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SELF-INDUCTION OF ELECTRICAL CONDUCTORS.

IF Professor D. E. Hughes does nothing else during his tenure of office in connection with the Society of Telegraph Engineers and Electricians, his presidential address will always remain a memorable incident in the transactions of that body. It is a masterly compilation in its very simplicity, and the author deserves the warmest thanks of the whole electrical community for the light which he has thrown upon matters which until now had been more or less obscured and but little understood.

The manufacturers of dynamo-electric machines will see their way to improvements in the form of the conductors employed, both in armatures and field-magnets, and in the methods of coiling, for if the self-induction of a current upon itself may be reduced to a mere fraction of its previous force by simply separating the contiguous portions of a current from each other, the advantages of employing ribbon conductors, or a series of ribbons, will not be overlooked.

The curious effect which the Professor has observed in mixed or alloyed conductors will, no doubt, be taken full advantage of in the construction of telegraph and telephone lines.

The "Lightning Rod Man" may now take it as an indisputable fact that a flat copper ribbon conductor, or, if of iron, a stranded rope or wide ribbon of similar conductivity to the copper, should invariably be employed; a solid rod of iron being the worst possible form for a lightning conductor. This point cannot be too strongly urged upon those in whose hands is placed the protection of buildings from lightning, for here self-induction exhibits its worst effects.

The manifold subjects upon which Professor Hughes has touched will be found fully reported in our other columns, but before closing these remarks we cannot refrain from expressing the belief that immediate improvements in our telegraphic and telephonic service will be the direct outcome of these masterly researches. The advantages of using carbon as a resistance for special purposes is fully pointed out, and, indeed, there is but little in electrotechnics upon which the Presidential Address to the Society of Telegraph Engineers and Electricians does not give some valuable information.

Further comments upon certain portions of the address may be found in "Note" form.

MACHINERY IN MINES.

ON Wednesday, the 27th ult., a paper entitled "Machinery in Mines" was read before the Society of Arts by Mr. Henry Davey, M.Inst.C.E.

That portion of the discourse in which we feel most interest is devoted to the transmission of power and ventilation in these underground workings, which extend to great distances, and cover large areas. Animal power, the lecturer states, is almost entirely superseded by machinery, and he alludes to two systems only for actuating hauling engines, viz., the compressed air and the hydraulic methods. No mention is made of what can be accomplished by means of electricity, probably because the lecturer was not aware that it had been employed in any mine. Yet at the Trafalgar Colleries, Drybrook, Gloucestershire, ventilating and pumping machinery is actuated by electricity, and eventually the haulage of coals will be effected by similar means, an electrical locomotive being now in course of construction for this purpose. Mr. Davey showed how uneconomical, mechanically speaking, is the use of compressed air, for when experimenting with a pair of air compressors working underground hauling engines, the air being compressed to 54 lbs. per square inch, the total efficiency amounted to only 14·27 per cent., but when the pressure of compression was reduced to 40 lbs. per square inch, the total efficiency rose to 24·42 per cent. The experiments were conducted under precisely similar conditions, but the low efficiency in both cases is accounted for by the fact that the hauling engine did not use the air expansively. With hydraulic apparatus, however, better results are obtained, and Mr. Davey quotes a trial made at a colliery belonging to the Société Anonyme de Charbonwages des Bouches-dû-Rhone, by M. Biver, the engineer. The total efficiency of the whole system reached 54·2 per cent., *i.e.*, the total horse-power exerted by the steam engine was 229·2, and the work actually done by the hydraulic engines 124·2 horse-power.

For ventilation, mines were dependent, until the last few years, upon a furnace placed at the bottom of an upcast shaft. That system was very wasteful and had, also, serious practical objections; collieries are now generally mechanically ventilated by means of fans, whose general total efficiency is from 40 to 50 per cent. of the power applied.

For transmission of power, at least, electricity might be advantageously substituted for the present methods, at all events in mines which are not of a fiery nature. Perhaps the proprietors of the Trafalgar Collieries might not object to give the results of their experience in the use of electrical power in mines, an experience now of some years.

The Society of Telegraph Engineers and Electricians.—The next meeting will be held at the Institution of Civil Engineers, 25, Great George Street, on Thursday, 11th February, when a discussion on the paper of Prof. Hughes, "Self-Induction of an Electric Current in Relation to the Nature and Form of its Conductor," will take place.

THE SOCIETY OF TELEGRAPH ENGINEERS AND ELECTRICIANS.

WE understand that with the publication of No. 59 of the journal of this society, which has just appeared, and which concludes the volume for 1885, Professor Ayrton's editorship terminates. It may, therefore, be a convenient opportunity to consider what changes have been made in the journal during the seven and a-half years it has been under his management. In the autumn of 1878, when a new office, "The Chairmanship of the Editing Committee," was created, and when he was asked to accept it, the society was, we believe, largely in debt, owing upwards of £1,000, a large portion of which was due to its printers. The first step was, therefore, to arrange for the printing of the Journal being executed at a lower cost, but this could only be effected by the society being first freed from debt, in order that tenders for printing might be obtained from the principal London firms. Consequently a loan was subscribed among the members of the council to pay the society's debt. This being done, a contract with a new firm was accepted, at a rate which would enable the society to live within its means, and this large economy that Professor Ayrton carried out, combined with the collection by the treasurer of arrears of subscriptions, has enabled the society, not only to gradually become solvent, but to invest money from time to time as the equivalent of some of the life compositions of members which, when received in the old days, appear to have been regarded simply as yearly income, and spent for current expenses.

Glancing at the last number of the journal, we observe that it contains 32 abstracts from foreign periodicals, besides six pages of the names of other electrical articles appearing recently in the foreign periodicals, and which have not been abstracted. These are all of great value to students and readers of electrical literature, and add much to the worth of the journal. Turning now to numbers of the journal issued just before the commencement of Professor Ayrton's editorship, we do not find any abstracts at all from foreign periodicals in the proper sense of the word. All that the journal contained at that time, in addition to an account of the regular proceedings of the society, was a reprint, usually in full, of one or two articles which had already appeared in English in some other periodical. The volume for the year just ended contains 110 well-prepared abstracts; indeed, the index of the names of the abstracts is as long as the index of the actual proceedings of the society. In old days the yearly index of the Journal of the Society of Telegraph Engineers was, we remember being told, used by the Society of Librarians as a specimen of how *not* to make an index, the articles being actually indexed under the definite and the indefinite article, whereas of later years the index has been carefully compiled, many cross references being made so that each title of a paper or communication, or the reference to the remarks made by any speaker at a discussion, may be found indexed under *each* of the important words in the title. The marked difference in character between the index of the journal of to-day and of former years, is seen from the fact that, whereas the annual index for 1878, the year before Professor Ayrton became the editor, only occupied 2½ pages, the index for 1885 occupies 25 pages, and is therefore exactly ten times the length.

And this very marked improvement in the index is characteristic of the general improvement in the journal. Compared with the journals of other societies which publish their complete proceedings fully illustrated, the Journal of the Society of Telegraph Engineers and Electricians is *now* in front of that of any other society in rapidity of publication.

Cable News.—The cable steamer *Sherard Osborne* left Wellington, New Zealand, on December 7th, for Cook Straits, to repair the cable there.

ELECTRIC LOCOMOTION.

By A. RECKENZAUN.

VII.

MUCH misapprehension exists on the subject of the resistance to traction on tramways, or, in other words, the tractive force necessary to move a vehicle upon the road. One is accustomed to see small cars pulled by a single horse, and larger cars by a pair of horses, and only on very serious inclines one may observe an additional animal being brought into requisition to assist in the upward propulsion; it is therefore popularly assumed that the mechanical power necessary for tramway traction is something between one and three horse-power. Indeed, engineers themselves have frequently made too little provision in the range of power on tramway locomotives. On railways the resistance to traction is about 8 to 10 lbs. per ton, but such favourable conditions never exist in the case of tramways with grooved rails; and it has been found that grooved rails, when clean, on a straight line offer a minimum frictional resistance of 15 lbs. per ton.

Tramway rails are, however, exposed to much dirt, mud, stones, and to very sharp curves, and Mr. Henry Holt has ascertained that the resistance rises sometimes to over 40 lbs. per ton. Mr. Henry Hughes* deduced from experiments a tractive resistance of about 26 lbs. per ton; often more, occasionally less. Such high resistances are readily accounted for, when it is considered that the flanges of wheels frequently take a bearing on the bottom of the grooves, or on the dirt imbedded therein, at the same time that the wheels roll on the surface of the rail; for thus the wheel rolls on two different radii simultaneously, and grinding resistance is excited. Again, whilst the wheel at one end of an axle may be running on the proper bearing surface only, the wheel at the other end may be running with the flange against the rails. Sometimes the rails are a little out of gauge. Car-drivers know the value of a clear groove. One may tell you that the car requires a horse more power to draw it over clogged rails; another will tell you that it is equivalent to some hundredweights more load, or a ton or two more, according to the clearness of his perceptions. The horse would be the best witness, if he could speak his mind, but, failing his verbal evidence, the dynamometer must be consulted. Messrs. Merryweather & Sons, from their experience with steam tramway locomotives, have come to the conclusion that an average of 30 lbs. per ton may be taken as a data for the calculation of the ordinary tractive force to be provided for.

The force required for the starting of a car is necessarily much greater than the force required to maintain a uniform speed, and experiments show that this initial pull amounts to from three to four times the tractive force on the level, or from 90 to 120 lbs. per ton.

In the case of electrically propelled cars it is easy to record the variations of the motive power on any line. An ammeter inserted in the circuit will show the slightest changes in the conditions of the road; the needle will rise and fall with every alteration of the coefficient of friction between the wheels and rails; and if such coefficient were constant and the instrument very sensitive it would show the exact difference of motive power which each passenger would occasion by entering or leaving the vehicle.

In going round a curve of 50 feet radius the resistance to traction is doubled, and even trebled, if there is sand on the rails; but when the rails are wet this resistance, due to curvature, is reduced. With a very short wheel base, or better still with radiating axles or bogies, the motion on curved rails is considerably facilitated.

On tramways in towns it is not convenient to raise the outer rail of a curve to a higher level than the inner rail; there is no safeguard against effects of the

* "Tramways," D. K. Clark.

force tending to keep the moving mass in a straight line; it is therefore all the more desirable to provide flexible wheel bases, in order to prevent the wheel flanges from riding over the inner edge of the rail and thus leave the described path. In the case of cars pulled by horses this tendency to leave the curved rails is much lessened by virtue of the side pull caused by the animals who keep in the middle of the track.

The effect of gradients is a matter of simple calculation, and it must be provided for in designing a motor and estimating the maximum power requisite on any given line.

Given a tramcar weighing 2 tons, 40 passengers 2·5 tons, electric motor and gearing ·5 ton, what power must be provided so that the vehicle may mount an incline of 1 in 40 at the rate of six miles an hour?

The resistance to traction on the level road will be $5 \times 30 = 150$ lbs., which, pulling at the rate of 528 feet per minute, gives $\frac{528 \times 150}{33{,}000} = 2{\cdot}4$ effective H.P.

The resistance due to gravity will be $\frac{2240}{40} = 56$ lbs. per ton, or a total downward pull of 280 lbs., which at the given speed causes an expenditure of $\frac{280 \times 528}{33{,}000}$ = 4·48 H.P. effective; therefore the total effective energy to be provided for is 6·88 H.P. upon the driving axle. To this we have to add the power lost in the mechanical transmission, and also the energy lost in the motor itself in order to arrive at the current and E.M.F. necessary to drive the motor. Taking the efficiency of the gearing at 85 per cent. and the efficiency of the motor at 75 per cent., then we require 10·8 electrical H.P. at the terminals of the electro-motor, which is equivalent to 7,949 watts. With an E.M.F. of 120 volts we should thus require 66 ampères of current when mounting an incline of 1 in 40, and only 23 ampères when running on the level road, assuming that the efficiencies are the same at different horse-powers, which, however, will not be the case if one motor only is employed.

The starting (initial) current, as already shown in our previous article, depends upon the resistance of the motor circuit. The statical pull, or in other words the attraction between the armature and the field magnet at the moment of starting depends upon the strength of the current, and in a series-wound motor this statical force is approximately proportional to the square of the current strength, therefore it may be safely assumed that a motor which is capable of propelling the car at the rate of six miles an hour on any road will also be powerful enough to start it on every part of the line provided that the magnet coils are joined in series with the armature, and provided, also, that the supply of current from the generator accords with the requirements of the motor. If the motor is shunt-wound, then the conditions are altered, as the armature alone will get the excess of current at starting whilst the field is constant. Compound winding of the motor will satisfy to a greater extent the two requirements, viz., a reasonably large statical pull at starting, and a certain constancy of speed when running with a variable load. But we hope to return to this subject of winding and the effects produced thereby at some future time; meanwhile we occupy ourselves with the consideration of the general efficiency of the various systems of electrical traction, the adaptability of one system or another to special circumstances. The system requiring separate conductors for the transmission of electric energy has its advantages and disadvantages, so has the system of secondary batteries, and as we advance in knowledge and experience so will each find its proper sphere of operation.

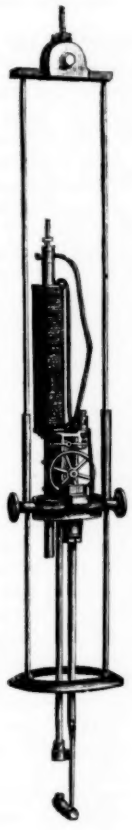
Sixpenny Telegrams.—The increase in the number of telegrams despatched in Aberdeen during the past year was 80,000. This increase, it is said, dates from the introduction of the sixpenny rate.

THE NEW STATTER ARC LAMP.

THE design of this lamp is essentially a practical one, and the aim of the inventor has been to produce a lamp which shall work well in the hands of an unskilled workman.

The regulation is effected by a solenoid, usually compound wound, and the mechanical parts used to effect the desired striking and lengthening of the arc and the feeding of the carbons are simple, strong, and few in number, and have an action easy to understand. The solenoid and its core are proportioned to respond readily to changes in the length of the arc, and, at the same time the position of the core is one of definite equilibrium and resists any attempt to make it oscillate or "pump."

In the single lamp shown in the figure, the rod carrying the upper carbon is a rack rod and it gears with a pinion, on whose arbor the deeply grooved brake wheel shown in the figure is fixed. A small steel chain, fastened to the core of the solenoid, takes



one turn round the brake wheel and is then attached to a small weight in the guide tube shown in the woodcut (projecting below the body of the lamp). Before the current is switched on to the lamp the weight rests upon the bottom of the guide tube, and the loop of the chain rests loosely in the groove of the brake wheel and leaves it free to revolve. On switching on the current the core is drawn up and the weight raised to hang upon the lower end of the chain. The wheel is now firmly "noosed" by the loop; the core is still drawn up, the wheel revolved and the rack rod wound up by its pinion. Thus the arc is formed, the core continuing to be lifted up until, by the increasing power of the shunt coils, it arrives at a point of equilibrium. To feed the carbons the core descends, at first allowing the wheel to revolve with the chain, and, afterwards, when the weight is stopped in its descent by falling upon a spring at the bottom of the guide tube, and part of its weight is in this manner taken off the chain, the wheel can slide under the chain, and so allow

the upper rod to descend. Should, however, the speed of the engine driving the lights be suddenly increased the core will be drawn up and the rack rod again wound up, thus widening the arc, and should this increased speed be maintained the lamp will regulate as before, but with a longer arc; and in this manner the dynamo is protected by the lamps from being overheated by an excess of current being passed through the armature.

The lamp is constructed with interchangeable parts, gauges and cutters to set to gauge having been made for all the parts. By loosening a milled headed screw the rack rod may be taken out and cleaned. The case and raising and lowering arrangements are simple but handy, and designed with the view of reducing the amount of attendance.

The lamps are made in three stock sizes to burn with 7 to 10 ampères, 10 to 15 ampères, and 15 to 20 ampères.

The same mechanism is applied to a lamp having two rack rods, and these double lamps are made to burn with the same currents as the single; they burn for about 16 hours without a replenishment of carbons.

ELECTRIC LIGHTING OF STEAMSHIPS.

S.Y. *Mohican*.—This very handsome steam yacht, of 700 tons, belonging to Mr. John Clerk, of Paisley, which has just left the Clyde for a few months' cruise in the Mediterranean, was fitted throughout with the electric light to the specification and under the inspection of Principal Jamieson, College of Science and Arts, Glasgow, by Messrs. Norman & Son, of that city.

The plant consisted of a high speed Gwynne engine, driving direct an Andrews compound "Woodside" dynamo at 350 revolutions per minute, as well as 30 one horse-power E. P. S. accumulators. The whole of the circuits were wired on the "return wire" plan, and when in full operation there were 92 glow lamps, assorted power in accordance with the position they occupied in the ship at 16 or 10 C.P. respectively.

The engine and dynamo were bolted to one bedplate close to the starting platform of the main engines, and the various switches so arranged that (1) the accumulators could be charged alone; (2) the accumulators could be charged and at the same time any or all of the lamps on board lighted. In this case the accumulators formed an excellent regulator for the dynamo (just like an air vessel on a pump), and kept the lights absolutely steady. (3) One or all of the lights could be worked direct from the dynamo at pleasure without any connection with the accumulators. (4) Some 30 lamps could be worked for a few hours direct from the accumulators when it was desirable not to have steam up, such as on a Sunday night when lying in port, or to keep a certain number of lamps going should the engine or dynamo be stopped for inspection or repairs at any time.

Any of these four different ways of working the circuits could be brought into operation in less than half a minute. The behaviour of the accumulators will be watched with considerable interest, as certain precautions were taken to prevent a recurrence of the failures which have as a rule hitherto attended their use on board ship. In many instances they will be found very useful, and fully repay the extra cost of fitting them on board.

SS. *City of Bombay*.—This, the latest addition to the well-known City Line of steamers, has just been completed at Glasgow, and left for Liverpool previous to taking her turn on the company's route to and from India, &c. She has been fitted with the electric light in the engine and boiler rooms, saloon, officers' and passengers' accommodation, &c., as well as with "mast-head lights" and "side lights," to the number of 112, by Messrs. J. D. F. Andrews and Company, the consulting electrician for Messrs. George Smith & Son (the managers of the City Line) being Principal Jamieson, Glasgow College of Science and Arts. The generating plant consists of two separate and independent vertical 10 I.H.P. engines, by Marshall and Sons, running at 155 revolutions, each driving by a belt a compound-wound Andrews dynamo, at about 450 revolutions per minute. Each engine and dynamo is capable of easily working any of the circuits on board up to 80 lamps, and both engines and dynamos, when at work, have an easy time of it with the whole of the lights on. The mast and side lights seem to give great satisfaction, and by a simple arrangement, devised by Mr. Andrews, should one lamp break down, another automatically comes into circuit, so as to minimise the chance of these most important lights being out at any time. The wiring throughout has been done on the "single wire system," that is to say, the beams and plates of the ship have been utilised instead of return wires to the dynamo for completing the circuit. A number of letters having lately appeared in the *Nautical Magazine*, drawing the attention of ship owners and captains to the dangers that may arise from this now very popular system of wiring ships, especially to the ship's compasses, the consulting electrician and the compass adjusters, took advantage of the opportunity afforded during the adjustment of the compasses to see if there was any such effect observable on board the *City of Bombay*. The whole of the lights were simultaneously turned on and off alternately several times, and it was found that the current in the wires produced a steady permanent error of five degrees on the steering compass, and two degrees on the standard compass (Sir William Thomson's), although the nearest wire was about 12 feet from the latter compass. Of course, such an error was not permitted to remain, and the wires have been so run as to remove all chance of any compass error arising therefrom. It would in our opinion be very advisable if all ships fitted with the electric light were carefully tested in the manner stated above, for if such an error existed unknown or imperfectly known to the officers of the ship, and only appearing when certain parts of the ship was lighted at night, and on certain courses, the consequences might be very serious. Five degrees error on the night course of some of our fast speed mail boats would mean ten miles or more out of position in the morning.

BLEACHING BY ELECTRICITY.

THE idea of bleaching by electricity is by no means new, indeed the early discovery of ozone generated by electrical means and the well-known powerful bleaching property of the same obviously at once suggested the possibility of an electrical process for bleaching coming into use. Several years ago the electrical bleaching of sugar was, we believe, carried on by a firm of refiners in Lambeth, the electricity for the purpose being generated by a Wilde machine. Whether the system is still in operation we are unable to say, but the fact that practically nothing has been written or published on the general subject would seem to indicate that bleaching by electricity has not been really practicable. Recently the subject has been again taken up, and this time with good prospects of success; this is owing to a discovery of M. Hermite with reference to a chemical reaction which takes place when the chlorides of the alkaline earths, and notably chloride of magnesium, are submitted to electrolysis. The chlorine in the substance under the action of the electric current has a powerful bleaching action, though, curiously enough, no waste of the substance takes place, the chloride becoming, it is stated, regenerated automatically. Thus if indigo be in solution with the chloride bath and platinum electrodes be employed, the colour becomes discharged by the action of the electric current without any sensible disengagement of chlorine. The principle has been practically applied for the bleaching of cotton goods and, we are informed, with excellent results, the fibres being far less injured by the new process than is the case under the ordinary method; this is due to the action being completely under control.

THE SEAT OF THE ELECTROMOTIVE FORCES IN A VOLTAIC CELL.

Some Notes by Professors AYRTON and PERRY, on Dr. Lodge's Paper.*

THE value of the historical part of Dr. Lodge's paper can hardly be overrated. A fair share of credit has been given in it to all experimenters on contact forces, and his description of the different kinds of apparatus used by the various investigators is very clear and very helpful, but we certainly object to the unproved assumption running all through his paper, that there is a *primâ facie* absurdity in acknowledging a considerable difference of potentials between two metals, such as zinc and copper, in contact with one another.

He says that all the apparent differences of potential which have been measured in air are due to an air-effect; and when these same differences of potentials are obtained by measurements in gases quite different from air, he still says that they are due to an air-effect, and even that when they are obtained from measurements made in a fairly good vacuum, they are still due to air-effects. In fact, he considers that he has good reason for concluding that the existence of a large contact potential difference between metals is absurd, and he boldly puts forward the view that if measurements were made in the most perfect vacuum hitherto obtained in the laboratory, and if the results were still the same (as they probably would be) they would still be due to air-effects. Now, when it is borne in mind that all the experimental evidence is in favour of the existence of a real large contact potential difference between metals, it is quite evident that our most important duty is to examine the basis of the strong reason which has caused Dr. Lodge to discard direct experimental results, for it is this strong reason which has caused him to enter into elaborate explanations as to the attraction between gases and metals.

We will first dispose of that part of Dr. Lodge's paper which is not debatable, viz., the seat of the E.M.F. in a voltaic circuit. So far from differing from Dr. Lodge on this point, we believe that we are in agreement; and we hope to prove that this seat of the E.M.F. in a voltaic circuit has really nothing whatever to do with the potential difference between zinc and copper in contact. In fact, Dr. Lodge's paper has not got quite its proper title. The subject to which the greater part of his paper is devoted is a debatable one, but it is quite a different subject from that of the seat of the E.M.F. in a voltaic cell. In considering this latter subject we shall, for brevity's sake, regard the small Peltier effect as non-existent. Formerly, any cause of flow of electricity was called an E.M.F., and hence in stating Ohm's law, E.M.F. and potential difference were used indifferently. But when we adopt, as everybody does nowadays, the exact definition of Clerk Maxwell, we must be more careful; and when we adopt the much more guarded definition of E.M.F. of Dr. Lodge, we must be particularly careful. This definition of Dr. Lodge is given in two quotations from Clerk Maxwell; and the definition is not merely the definition of E.M.F., but is the definition of the seat of the E.M.F. *The seat of the E.M.F. in any circuit is the place at which the circuit receives or gives up energy as distinct from heat due to resistance, and the amount of the E.M.F. is measured as the amount of energy which enters the circuit per unit of electricity passing that place.* Now it is not possible with such a definition of E.M.F. as this, to give any answer to Dr. Lodge's question different from the one he has himself given. The seat of the E.M.F. is practically defined to be the place where the chemical action goes on. It follows, therefore, that the place where the chemical action goes on is the seat of the E.M.F. The answer is given in the definition, and the definition is merely a partial statement of Sir William Thomson's result—that the E.M.F. of a voltaic circuit can be calculated from the chemical action going on.

The important subject, however, taken up in Dr. Lodge's paper is, as we have already stated, quite a different one. He finds strong reasons for believing that there cannot be a considerable difference of potential between zinc and copper in contact. In fact, a large difference of potential is to him logically absurd, and he devotes the paper to speculations as to how experiments could have misled Sir William Thomson and others into believing such an absurdity. The absurdity is so obvious to Dr. Lodge, that it might have struck him, perhaps, that Sir William Thomson might also have seen it. However, as Dr. Lodge has the opinions of Clerk Maxwell and many others on his side, the question is a fair subject for debate, and we shall endeavour to show that our notions on the subject do not lead to any absurdity. With his definition of E.M.F. we have never stated that there is such an E.M.F. due to contact between zinc and copper. We deny that there is such contact E.M.F., but we do say there is contact difference of potential. We do not say that what has been measured may not be to some, even to a large extent, due to air effect; indeed, in our third paper on the Contact Theory of Voltaic Action, in Part I. of the Phil. Trans. for 1880, we drew especial attention to the possibility of air effects, and we showed, exactly as Dr. Lodge now shows, that our measurements gave no indication as to whether there is or is not an air effect. But we contend that no such air effect has ever been observed, and until it is observed we cannot admit that there is strong reason for believing in its existence, especially since we shall prove that all the phenomena of contact action can be rigorously explained without the necessity of resorting to any air action.

Dr. Lodge says that if electricity rises in potential from copper to zinc, there must be a supply of energy from some outside source at the place of contact. We ask him why he should make such an assumption? Putting on one side the question as to what is exactly meant by electricity rising in potential at a point, or by the potential inside a wire through which a current is flowing, we are willing for the sake of his argument to assume that in taking a unit of electricity from a point in a section of the wire to the outside and from that through the dielectric, and from that into the wire to a point in another section, the work that must be done is the same for any points in the sections as Dr. Lodge assumes, and to take that work as the measure of the difference of potential between these two sections; and still we ask him why we must assume that, when electricity rises in potential suddenly at a place in a circuit, energy must come in from the outside to enable the electricity to rise in potential? Suppose we grant that electricity gains in potential energy in flowing from copper to zinc, do we know so much of an electric current as to assert that when the electricity gains potential energy it does not lose an equivalent quantity of some other kind of energy? Why may we not assume, for example, that electricity loses tension energy in passing from copper to zinc, so that if it gains potential energy it loses tension energy. From that point of view, part of the function of the liquid in the cell would be taking electricity from the zinc to the copper inside the cell, giving it tension energy, and this tension energy is converted into potential energy when the electricity passes in the outer part of the circuit from copper to zinc.

But, indeed, there is no need to assume the existence of a tension energy. Why should we assume that work must be done by outside agents at a place in raising electricity from potential A to potential B? By definition work will be done if we take electricity through the dielectric from A to B, but it does not follow that an outside source must do work in carrying electricity from A to B through the wire itself. We know so little of what is really meant by the electric current, and the mechanical analogies which have been put forward from time to time are so imperfect, not even excluding the beautiful form that Prof. Poynting

* *Philosophical Magazine.*

has given to Clerk Maxwell's analogy, that we like to fall back upon the oldest and simplest one, which is that, when electricity is flowing in a wire, at one end it is being continually thrust in, and at the other end it is in consequence continually being thrust out, just for the same reason that electricity tries to come to the outside of bodies—repulsion of electricity by electricity. Hence in the case of a copper wire one end of which is joined to the copper plate of a battery and the other to the zinc plate, electricity is being pushed into the copper wire at the end where it is connected with the copper plate, and at the other end is pushed out of the wire into the zinc plate. If at the zinc end, electricity can only get away by rising in potential, then it rises in potential, but the energy, which there becomes potential-energy, comes from the battery, and it is not necessary to get a supply of energy from any outside source.

Of course this is only an analogy, but when we speak of electricity flowing in a wire, we are using an analogy which is derived from electrostatic and hydraulic phenomena to explain a phenomenon of an electro-kinetic kind. The idea of a tension energy in electricity as distinct from a potential energy may be objected to as being new and unnecessary, but in spite of our very exact knowledge of mechanics we have the same sort of difficulty in many mechanical arrangements unless we assume the existence of a tension energy. For example, suppose you have a winding engine and a long endless inextensible rope passing over pulleys, horizontal in places, vertical in places, and coming back to the engine again, and at one place there is a weight being lifted. Now work is being done on that weight in lifting it. But energy does not come from the outside into the circuit there; it comes from the winding engine; it comes somehow through the rope. Energy disappears at the winding engine and appears as work done in the weight being lifted. In what form is it before it is converted into potential energy? The energy is conveyed. In what form is it when it is in the rope? We really do not know, or, rather, we have not given a name to it. But if we must give a name to it, it is tension energy. We know that there is a difference in the tension of the rope above and below the weight which is being lifted. Difficulties of this kind are really due to the fact that the notion of conveyance of energy from one point to another has not yet been co-ordinated with the ordinary exact definition of energy. The energy which we usually speak of as being possessed by a portion of matter, or as existing at a particular place, is really possessed by a much larger system.

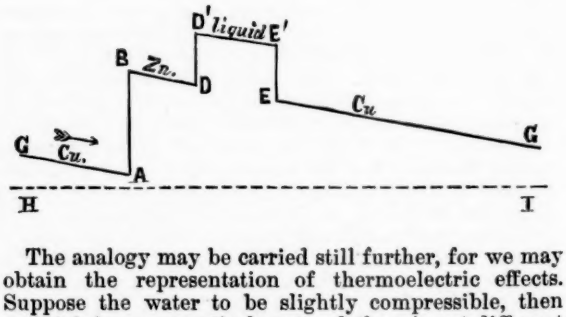
The analogy, however, which Dr. Lodge has used for showing, as he considers, the absurdity of our position, is the hydraulic one, but even with the analogy, when properly interpreted, no such absurdity is found to exist. In fact the explanation mentioned by Dr. Lodge in his paper as having come through one of us from Sir William Thomson, but which must really be regarded as having come from ourselves, as we think that Sir William has probably his own distinct method of looking at the matter, has been misapprehended by Dr. Lodge.

Suppose we have a circuit of pipes, G, A, B, D, D′, E′, E, G, whose development is shown in the figure, the two ends of the figure, G and G, being the same point in the real circuit; the pipes to be of uniform section, and to rise suddenly in level from A to B and from D to D′, and to fall from E′ to E, and there being a uniform rate of fall from B to D, D′ to E′, and from E through G to A. H, I may be any datum-level. Let us suppose that there is a continuously-acting pump in the part D′, E′, causing incompressible fluid, such as water, filling the pipes to flow continuously. Mechanical energy is given to the pump from some outside source, and the energy reappears at various places in the circuit. Thus, for example, between A and B the water rises in level. A pound of water at B has more energy than a pound of water at A, and its increase of energy is h foot-pounds, if the difference of level is h feet between B and A. It has really gained energy. What has it lost? Pressure, certainly; but pressure is not a form of energy. We know that in a steady frictionless stream

$$\frac{v^2}{2g} + 2{\cdot}3\,p + h$$

remains constant, if v is the velocity in feet per second, and p the pressure in pounds per square inch, and h height in feet above datum level. As $\frac{v^2}{2g}$ is the kinetic energy of a pound of water in foot pounds, and h is its potential energy, one is tempted to call $2{\cdot}3\,p$ also a form of energy—pressure energy; but we have just as much, and no more, right to call it so, than to speak, as we did, of tension energy in electricity. We can see that pressure conditions are not in themselves a source of energy, by imagining incompressible fluid, like water, filling a closed vessel at great pressure, and then imagining an orifice to be made, when, of course, the water is no longer subjected to great pressure. But $2{\cdot}3\,p$ enters into the expression and is familiarly spoken of as a form of energy when the stream is *steady*—when there is a continuously-acting pump somewhere in the circuit. In fact, then, we see that when a pound of water rises in level from A to B it receives h foot-pounds of energy if h is the difference in level, and it receives no energy from an outside source at A, B; energy disappears in the pump, and work is done between A and B. Now, just as difference of potential in electrical things is measured as the work which must be done, on unit of electricity, in taking it from one point, A, to another, B, *through the dielectric*, so the difference of level between A and B represents the work done on a pound of water in taking it from A to B *through the air*. And just as the water is being raised from D to D′ gains energy *without any work being done on it from an outside source*, so we may consider that electricity in passing from copper to zinc may gain potential energy *without there being any external source of energy at the junction*.

The preceding is even more than an analogy. There is a tendency for electricity to leave copper and enter zinc at the junction, which we are now prevented from calling the E.M.F. of contact, but which we may call contact force. It is measured as the difference of potential established between two metals which are in contact. There is no contact force in a piece of copper or in a piece of zinc. The contact force is analogous with pressure in water. There is a sudden rise in level in the pipe from A to B which corresponds with a sudden rise of potential from copper to zinc. There is a consequent diminution of pressure from A to B which corresponds with the contact force at the junction. There is no contact force in a copper wire; and hence it is necessary to give to the pipe such an inclination that the potential energy lost by the water in flowing along the pipe shall be equal to the energy given out in friction. In the voltaic circuit, similarly, the fall of potential energy is known to be equal to the heat produced in overcoming resistance.



The analogy may be carried still further, for we may obtain the representation of thermoelectric effects. Suppose the water to be slightly compressible, then maintaining any vertical parts of the pipe at different constant temperatures will help or oppose the action of the pump in the circuit. Thus, not using a pump, let there be an endless pipe, rising suddenly from A to B, horizontal from B to C, falling suddenly from C to D, and horizontal from D to A. Imagine this filled with

a slightly compressible fluid, and that the limb, C, D, is permanently kept at a higher temperature than A, B, there will be a steady flow maintained in the direction A, D, C, B, A. If the limb, A, B, is the higher in temperature, the flow will be in the direction A, B, C, D, A. Strictly speaking, we ought to consider the fluid in the endless tube to be one which changes the law connecting its density and temperature at a critical point, like water at 4° C.

To be quite correct, let what we have called "tension" in a metal, a, at the absolute temperature, t, be denoted by ${}_t\mathrm{P}_a$; and the increase of potential from a to a metal, b, as measured inductively, by ${}_t\mathrm{V}_{ab}$, then the E.M.F. of a thermo-electric circuit of two metals, a and b, whose junctions are at temperatures t_1 and t_2, is

$$\mathrm{E} = {}_{t_2}\mathrm{V}_{ab} - {}_{t_1}\mathrm{V}_{ab}.$$

The Peltier effect at a junction is

$${}_t\Pi_{ab} = {}_t\mathrm{P}_b - {}_t\mathrm{P}_a - {}_t\mathrm{V}_{ab},$$

where

$${}_t\mathrm{V}_{ab} = (k_b - k_a)\, t \left\{ \mathrm{T}_{ab} - \tfrac{1}{2}\, t \right\} + \mathrm{C}_b - \mathrm{C}_a.$$

and

$${}_t\mathrm{P}_a = \tfrac{1}{2}\, k_a\, t^2 + \mathrm{C}_a.$$

k_a and C_a are constants peculiar to the metal, a, and T_{ab} is a constant peculiar to the two metals, a and b.

Hence

$${}_t\Pi_{ab} = t\, \frac{d}{d\, t} \cdot {}_t\mathrm{V}_{ab},$$

or the Peltier effect is proportional to the product of the absolute temperature into the rate of change of contact potential difference with temperature. Consequently, *although the amount of heat generated when a unit current is sent through a junction for a second is the measure of the coefficient of the Peltier effect, this coefficient is in no sense a measure of the contact potential difference existing at the junction.*

This really disposes of Dr. Lodge's fundamental argument—the argument, in fact, on which his whole objection to the large contact-potential difference at the junction of metals is based; for he *assumes* that in all cases where there is a considerable difference of potential at a junction, heat or cold must be developed when a current flows across that junction. He states, what is quite true and well known, that practically no heat is developed when a current flows from zinc to copper across the junction; therefore he concludes that there can be no contact-potential difference at this junction like three-quarters of a volt. But if, as we have proved, the coefficient of the Peltier effect is *not* a measure of the contact potential difference, but of the product of the absolute temperature into the rate of variation with temperature of the contact potential difference, it follows that the smallness of the Peltier effect does not require that the contact potential difference must be also small.

We have endeavoured to experiment on this rate of variation of the contact potential difference with temperature; and in the discussion on Dr. Lodge's paper before the Society of Telegraph Engineers and Electricians, we gave a number of hitherto unpublished results which we had obtained on this subject. The apparatus we employed was the same as that which Dr. Lodge described as being used by us in our former experiments on contact potential difference, and with it we measured the contact potential difference of hot and cold mercury and of hot mercury and cold iron, hot mercury and cold copper, also for hot mercury and cold platinum, in each case for various differences of temperature. The results obtained were large (amounting in the case of mercury and iron to as much as 3 volts for about 16° C. difference of temperature), and not small, as might have been expected from the preceding equation and the smallness of the coefficient of the Peltier effect. We explained, however, that the very large potential differences we obtained were probably due to *invisible* films of oxide on the surface of the warm mercury, which probably existed in spite of the fact that every effort was made to remove this oxide by distilling the mercury between every two sets of experiments; and we showed that in such cases the summation law does not hold true—that is to say, the E.M.F. of a combination is not equal to the algebraical sum of the various potential differences at the contacts, *measured inductively*, and which we have always found to be true in other cases when the experiments were conducted with as much care as was devoted to those made with hot mercury. For example we found that

Copper at 16° C., with *clean* mercury at 16° C., had a contact difference of 0·308 volt;

Mercury at 16° C., with mercury at 26° C., had a contact difference of 0·75 volt;

Mercury at 26° C., with copper at 16° C., had a contact difference of − 1·5 volt.

Therefore, if these numbers represented the true contact potential differences, a thermopile consisting of two pieces of cold copper at 16° C., dipping into two vessels of mercury, one of which was warmed up to 26° C., and which were joined together by a syphon tube containing mercury, ought to have an E.M.F. of half a volt. But, as was to be anticipated, we found experimentally that no such E.M.F. could be obtained with such a thermopile, unless there were an oxide present at the hot junction separating two of the metals, and thereby introducing a high resistance.

Contrasting these results with those given in our papers read before the Royal Society (and which prove conclusively that when a cell is formed of a number of substances, solid or liquid, at the same temperature, its E.M.F. is equal to the algebraical sum of the various contact potential differences, *measured inductively*, in air, of each of the pairs of substances in contact in the cell), we are justified in concluding that when layers of oxides or their salts are formed on the surfaces of the substances employed, as in Mr. Brown's experiments, the measured potential differences do not represent the true contact potential differences of the substances employed.

We are not disposed to think that Dr. Lodge has discovered any striking coincidence between measured chemical heats of combination and those heats as calculated on his theory. Such coincidence as he has discovered is not more wonderful than that the electropositivity of the metals should be in the order of their tendencies to combine with oxygen; there can be no doubt that an exceedingly important advance in the sciences of chemistry and electricity will be made by the philosopher who explains this and the twenty other coincidences of a like nature which have been discovered. We are quite sure, too, he would regard the seeming coincidences which he has discovered as trivial, had he not at the beginning made up his mind that the existence of contact difference of potential was absurd, and that what we and many others have measured are due to air effects.

We are in the habit of using the expression "difference of potentials between two points" as meaning, in *Electrokinetics*, the *Electrostatic* difference of potentials between two copper wires, coming from the points. This practice is very convenient; and there can be no objection to it, so long as we do not imply that it is always the same as the *Electrostatic* difference of potentials between the points. Now it seems to us that Dr. Lodge, in following this convenient custom, has fallen into the error of imagining that what he has been in the habit of calling "difference of potential," is really the same as "*Electrostatic* difference of potential." Indeed, we believe that the root of the whole difficulty which prevented Clerk Maxwell, and which now prevents Dr. Lodge, from seeing the position of the contact theorists, lies in their defining potential in a new way not recognised in electrostatics. Clerk Maxwell's electro-magnetic theory is so perfect in itself that no one thinks of attacking it; and we very much wish that we had the leisure to show, what we feel might probably be shown, that throughout his mathematical work, when he speaks of difference of potentials it is not necessary to assume that he speaks of electrostatic difference of potential.

Dr. Lodge, in his reply to remarks made during the discussion at the Society of Telegraph Engineers and Electricians, was kind enough to mention the fact that we had drawn Prof. Poynting's equipotential surfaces and lines of flow of energy as they must be drawn in practice, most of them lying like successive sleeves in an infinitely shallow space round all the conductors in a voltaic circuit, if we are to follow Maxwell in assuming a considerable difference of potential between air and metals. As Dr. Lodge has stated, we have also drawn these surfaces and flow-of-energy lines on our own assumption of no air effect and considerable contact differences of potential. Dr. Lodge did not, however, refer to the very much more interesting curves which we have drawn as the energy lines from a primary voltaic or thermo-electric circuit whose current is altering just in such a way as to keep the current in a secondary circuit constant. Suppose it is the E.M.F. of the primary which is altering, it is very interesting to see how the lines of flow of energy sweep over the primary circuit, their parts which cut the secondary remaining unaltered. But now, suppose the total E.M.F. of the primary to be less than 1 volt, and imagine that Prof. C. Maxwell and Prof. Poynting and Dr. Lodge were right in their idea of a considerable difference of potential between air and metals, it will be found that no line of flow of energy can connect the primary and secondary circuits, since all the equipotential surfaces of the primary will lie infinitely close to the conductors of which it is composed, and yet it cannot be doubted that the secondary circuit receives energy from the primary.

For the purpose of evading all difficulties which might be due to our taking different numbers to represent possible contact differences between the parts of a voltaic circuit and air, let us test Prof. Poynting's deduction from Maxwell's theory in another way. Assume that there is a voltaic circuit completely enclosed in a hermetically-sealed metallic case; and let us suppose that, just before sealing up, we set up differences of potentials of many thousands of volts between the voltaic circuit and its case, and that it is in our power at any instant to cause any regular change of current in the voltaic circuit by means of mechanism enclosed by the case. Now let there be, outside the case, a secondary circuit, and let the primary enclosed circuit have its current diminished at such a rate that a constant current is maintained for a short length of time in the secondary by induction. We know quite well that such an inductive effect might take place, and that the energy of the secondary circuit must somehow come from the primary; and it must be remembered that it need not have been by a diminution of the primary current, but an increase of the primary current, that this induction takes place. We cannot see how it is possible that Prof. Poynting's electro-potential surfaces can proceed from the primary so as to pass through the secondary circuit; we can, however, imagine that, instead of equipotential surfaces, such as we speak of in electrostatics, if we speak of a series of surfaces cutting the lines of electrical displacement at right angles, then an explanation becomes quite possible. In fact, it seems to us that if Prof. Poynting's views are logically deducible from Maxwell's theory, it is necessary to assume that Maxwell's differences of potential are essentially different from electrostatic difference of potentials.

September 3rd, 1885.

Note added December 14th, 1885.

Since these notes of our remarks made in the discussion on Dr. Lodge's paper were sent to the Editors at the beginning of September, a paper on Contact Electricity has been read by Dr. Hopkinson before the British Association, and has appeared in the *Philosophical Magazine*. We are glad to see that Dr. Hopkinson, who has entered so fully into the energy equations, not only for Sir William Thomson's view, but also for that of Prof. Maxwell and Dr. Lodge, has come to the same conclusions as ourselves.

We leave our formulæ in these notes as they were written in April last, following Prof. Maxwell's lettering; but for the sake of those who may have studied that part of Dr. Hopkinson's paper which refers to Sir William Thomson's theory, it is well to state that

he uses $f(t)$ where we use ${}_tV_{ab}$,
" $F(t)$ " " ${}_tH_{ab}$,
" $\phi(t)$ " " tk_a,
" $\psi(t)$ " " tk_b.

REVIEW.

Situation of the Telephonic Systems.—Published by the Bulletin International de l'Electricité. Paris: Schiller.

This pamphlet will be exceedingly useful to all persons interested in the development of the telephone. An introduction notes the general position of affairs and brings to light the curious fact that in the two European countries where interurban communication is most extended and most successful, *i.e.*, England and Germany, the results are similar though the systems are quite different. In Germany telephonic working is kept strictly in the hands of the State, whilst in England it is entirely free. A series of tables shows the companies active in each country, the towns supplied, their population, the number of subscribers, the price of subscription, and where interurban communication is established, its extent. We find that, as far as Europe is concerned, Germany has the greatest number of systems (91) 70 of which have been established since 1883, and 14,733 subscribers. Great Britain follows with 89 systems, but has 15,114 subscribers. The prices of subscription vary greatly. Thus in the United States alone they range from 300 francs yearly at Providence to 750 at New York. In England the lowest charge, 200 francs, is at Accrington, and the highest, 500 francs, prevails at London, Manchester, Liverpool, Widnes and Glasgow. In Germany the scale is much more moderate, ranging from 62 to 185 francs.

LEGAL.

The Pall Mall Electric Association.—In the Chancery Division of the High Court of Justice (before Mr. Justice Chitty) on Saturday, the petition of Mr. G. J. Baker for the winding up of the company came on for hearing. Mr. Ince, Q.C., who appeared in support of the petition, said he did not propose then to ask for a winding up order, but only for some directions as to how the matter should be treated. The petitioner was a creditor, and the company, which was formed for the purpose of supplying electrical medical appliances, would, unless something was done to stop it, be dissolved in a few days in accordance with resolutions which had been passed to that effect. The claim was in respect of commission on the business carried on by the company, which was due to the petitioner under an agreement, and there would be questions raised as to what the business of the company was, and the amount upon which commission was payable. If it had not been that the company was about to dissolve, Mr. Baker would have brought an action in the ordinary way. If, however, his friend Mr. Romer, who appeared on the other side, would arrange matters so as to make it possible to adopt that course, his client would go on with his action, and consent to the petition standing over. Mr. Romer: In the agreement under which your client claims there is an arbitration clause. Why should it not be referred? Mr. Justice Chitty: Let the petition stand over for a week, and see if you cannot agree to refer the matter; and if so, take an order accordingly. Mr. Ince consented.

British Electric Light Company, Limited.—A petition for the winding up of this company was on Saturday ordered by Mr. Justice Pearson to stand over for a fortnight in order that some arrangement might be made for the disposal of the company. An application was made before Mr. Justice Chitty on the previous

day on behalf of the debenture holders for the appointment of a receiver, and his Lordship appointed the secretary of the company.

Otto *v.* Sterne. (Before Mr. Justice Pearson, Monday.)—This was one of the actions brought to restrain the infringement of Dr. Otto's patent for the silent gas engine. The defendants are Messrs. L. Sterne & Co., who are engineers carrying on business in London and at Glasgow. By consent judgment was now given for a perpetual injunction restraining the defendants from infringing the patent, no costs being given, and the defendants agreeing to take a license to use the patent.

The Grosvenor Gallery Lighting.—Mr. Charles Dixon Aria, of New Bond Street, appeared at Marlborough Street to an adjourned summons taken out at the instance of Sir Coutts Lindsay & Co., Limited, charging him with having on the 7th of July, 1885, in a certain affidavit filed in an action between Smethurst & Co. and Sir Coutts Lindsay & Co. in the High Court of Justice, committed wilful and corrupt perjury. The charge, which was before Mr. Newton in August last, arose out of an application to restrain the company, as proprietors of the Grosvenor Gallery, adjoining Mr. Aria's premises (Smethurst & Co.) from placing and erecting certain machinery therein for the purpose of electric lighting. It was alleged that the defendant, in his affidavit, falsely swore to the depth of his firm's cellars, and maintained that they were affected by the vibration of the machinery. Mr. Aria's statement was partly amended after the summons was taken out, and the question to be considered was, whether there was wilful perjury or not? The defence was, that the statements in the affidavit were made erroneously, and did not in any way affect the decision of Mr. Justice Chitty, when he granted an injunction, the matters they referred to not having been mentioned to the learned Judge when the application was made. On the case being called on, it was stated that the action was still pending, and, after legal arguments, Mr. Newton dismissed the summons.

NOTES.

Electric Lighting for Temporary Exhibitions.——At the recent Food and Cookery Exhibition held at the Royal Aquarium, the stalls in the exhibition were lighted by means of incandescent electric lamps. In many instances the material of the stalls was of a very inflammable nature, being composed of painted canvas, and containing lace curtains and ornamental paper, in which the employment of any other than the electric light was inadmissible. In the table decoration competition it played an important part; the effect of the lamps placed among the fruit and flowers, and also on the trees in the apartments, being extremely pretty. Upwards of 150 lamps were employed, the work being carried out by Messrs. A. R. Sennett & Co.

The Electrical Power Storage Company.—This company is busily engaged in installation work, to which branch of business it has been devoting special attention. The company has recently completed an installation at Mr. J. W. Logan's, Market Harbro', of 150 60-watt lamps, supplied by a 10 H.P. Marshall engine, placed about 200 yards from the house. It is now carrying out an installation at the Prudential Assurance Company's offices, where 1,500 lamps will be fixed when completed; also at Mr. Goddard's, Leicester; the Bank of New South Wales, Broad Street; Mr. W. Griggs' and Mr. F. D. Bumsted's. The company has recently undertaken the completion and working of the installation at Lloyds, where upwards of 500 lamps will be fixed when complete.

The Electric Light in the Royal Navy.—The *Alacrity* is being fitted at Portsmouth with the electric light, and will be ready for sea on May 1st next, when she is to be commissioned by Commander Le Strange, for service in the Mediterranean.

The Thomson-Houston Electric Lighting System.—The large factory of the Thomson-Houston Electric Company, at Lynn, Mass., is to be doubled in size and capacity, the immense business of the company requiring this addition.

A Chance for the Electric Light.—At a meeting of the Town Council of High Wycombe, a letter was received from the secretary to the gas company, stating that the directors, after carefully considering the charge for street lamps, were unable to reduce the same on the present terms, but that they were willing to supply gas to the street lamps at 3s. 9d. per 1,000 cubic feet, the sanitary authority, at their cost, doing the lighting, extinguishing, cleaning, and repairs. Several members observed that these terms would be no improvement on the present contract, and notices were handed in by Councillors Goodearl and Johnson, the former to move at the next meeting "That steps be taken to light the town by some other means than by gas," and the latter relating to the hours of burning gas in the street lamps.

Armington and Sims Engines.—The Armington and Sims Engine Company, of Providence, R.I., is said to be doing a heavy business, having for some time past run their works night and day. Fifty-one engines were shipped in November and December, and about sixty orders remained to be filled. The engine is meeting with great success in the electric lighting field.

Electric Lighting of Ingestre Hall.—The Earl of Shrewsbury has had Ingestre Hall lighted up with the electric light, which is supplied to every room in the house, and the stables and offices are also lighted. There are two 25 horse-power engines employed.

The Ball Electric Lighting System.—An installation of electric lighting on the Ball system has just been made in a large oyster house in Chicago, and much satisfaction is felt with its working in this particular case and in others where the much-condemned so-called "Unipolar" dynamo is used.

Electric Lighting of a New York Wholesale House.—The large wholesale house of H. B. Claflin & Co., occupying one-half the city block bounded by Worth, Thomas, and Church Streets, and West Broadway, New York, now possesses one of the most extensive and noteworthy private installations of arc and incandescent lighting in the country. The plant operated was furnished by the Mather Electric Company, of Hartford, Conn. All of the upper floors of this immense establishment are lighted by a total of 105 arc lamps, whilst the private offices, book-keeping department, the receiving and delivery departments, and a labyrinth of subways, are brilliantly lighted by 500 incandescent lamps, ingeniously arranged to secure an admirably even distribution of the light. The power room is situated in the lower portion of the building, and is about 40 feet long by 20 feet in width; it is brightly lighted by 16 candle-power lamps. In the middle, on either side, are planted two fine Buckeye self-contained engines, 13 by 16 inches cylinders, 75 horse-power nominal. There are, at one end of the room, one 500-light Mather incandescent and two 25-arc light machines, and at the other end one 30 and one 25 arc-light dynamos. The station was established on the 5th November last, and has run without a hitch or a stop since that date.

Electric Lighting of the Albany Capitol.—"When all the electric lighting appliances are completed for the Albany Capitol," said Superintendent F. P. Little, of the United States Electric Light Company, "the building will be the most extensively and brilliantly-lighted in the world. The capitol will take 4,000 incandescent lights, representing 64,000 candle-power; 100 arc lamps of 2,000 candle-power each, and 25 lamps each on the senate and west-end staircases, of 125 candle-power each. To run the incandescent lights will take seven dynamos, aggregating 600 horse-power, and one 20 and one 50 horse-power dynamos to run the arc lights. No isolated plant exists in the world so large as the one the capitol will contain, when the building is finished."

The Dalton Electric Lighting.—The Electric Lighting Committee of the Dalton Local Board has reported as follows:—"In continuation of their report, submitted to the Board in November last, the committee have to state that, having considered the report of the engineers (Messrs. Badger and Sons, of Rotherham), upon the condition of the engine and boiler originally proposed in his specification to be furnished by Mr. Menzies for electric lighting purposes, which the engineers found in many respects defective, and to require considerable repairs, the committee could not accept the same. The above recommendation is made to the Board for adoption, subject to the Local Government Board's approval of the electrical lighting scheme. That the offer of the Askam and Mouzell Iron Company to sell to the Board 200 yards of land on the east side of Duke Street be accepted, and that the clerk proceed to obtain title thereof and conveyance to the Board for production to the Board of Trade, in order to complete and give effect to the license. That the former resolutions of the Board in reference to the application for loan be varied as follows, viz.:—That application be now made to the Local Government Board for sanction to borrow the sum of £1,600 for electric lighting purposes, the repayment whereof shall extend over a period of 20 years." Mr. Hamer moved the adoption of the report. He said Prof. Jamieson's report showed that the place was well adapted for the light; it also suggested that they should have an additional dynamo in case of accident. The Board would get 120 lamps, with double the illuminating power, at the same price that they were paying for 60 lamps. They could with the proposed plant extend the number of lamps to 240 without extra men or labour. The total cost, including engine house, &c., would be £1,542. It had been thought wise to have a report as to the second-hand engine, and it had been unfavourably reported upon, and tenders were obtained for another engine and boiler. They proposed to apply for power to borrow £1,600, although he did not think the whole of this sum would be expended. At the same time the committee thought it advisable to apply for £1,600. The report was adopted.

Electric Lighting and Steam Boilers.—The *Contract Journal*, in a leading article, says:—Installations require steam power, and this means steam boilers. The use of steam boilers may or may not be attended with danger. The materials, the tools, and the practical knowledge requisite for the manufacture of boilers of such extraordinary strength as to almost render an explosion impossible are all at hand. The difficulty is to persuade the general public to credit this, and there is little doubt that fear of an explosion does much to deter those who would otherwise have installations from doing so. To promote the advancement and general adoption of electric lighting, two things must be done as regards the steam power. One is to take the most effectual precautions against a disaster taking place, and the other is to inspire the public with confidence.

Proposed Adoption of the Electric Light at Hanley.—The Hanley Town Council has appointed a subcommittee to consider the desirableness and the cost of lighting the public buildings, and eventually the streets of the borough, by electricity.

The West London Electric Lighting.—The Vestry Board of St. James's, Westminster, has decided to request the Board of Trade to oppose the Bill of the West London Electric Lighting Company, and will itself oppose the draft provisional order as a whole.

Domestic Electric Lighting.—The residence of Col. Miles, M.P., Burtonhill, Malmesbury, is to be lighted by the electric light; about 150 lamps will be employed. The work has been entrusted to Messrs. A. R. Sennett & Co.

Large Isolated Plant.—At Two Rivers, Wis., an isolated plant covering an area of one-half by one-quarter of a mile has just been placed by the Edison Company, which furnishes illumination for mills on opposite sides of the river, one of these being supplied through an armoured cable laid in the river bed. This is a new departure, and is reported a perfect success.

The Portsmouth Telephone Exchange.—At the annual meeting of the Portsmouth Chamber of Commerce, the President (Mr. J. Bonham Carter, J.P.) in the chair, the report which was presented to the members stated that the telephone exchange opened at Portsmouth, mainly by the action taken by the Chamber, now numbered over 50 subscribers, and it was hoped it would be more used by commercial members throughout the scattered districts of the borough. To make it still more useful the council hoped to arrange with the telephone company to establish places of call in the four districts of the town. The Chairman acknowledged the liberal spirit in which they had been met by the Western Counties and South Wales Telephone Company, and expressed the opinion that with 59 subscribers as a nucleus they might expect that the exchange would increase rapidly. He hoped to see the exchange number its hundreds.

Professor Gray's Telephone.—A company with $10,000,000 capital has been formed at Chicago to work Prof. Elisha Gray's telephone patent and protect his interests in the Courts.

Telephone Wires in Edinburgh.—The Edinburgh Town Council has decided to accept the estimates of the National Telephone Company for a wire from the Exchange to the City Hospital at £15 per annum, and for a wire to the City Chambers at £10 per annum, and the estimate of Alexander Maclean & Co. for a wire from the City Hospital to the office of the Medical Office at £5 per annum.

Increased Telegraphic Facilities at Portsmouth.—Thanks principally to the efforts of Count Metaxa, a resident, an application has been made to the Treasury for the Albert Road Post Office at Southsea to be made a receiving office for telegrams, and the change will be made as soon as the necessary permission has been obtained.

A Generous Gift.—Mr. J. W. Mackay, the Silver King, has presented all the employès of the Commercial Cable Company in America and in Europe, from the general manager to the humblest messenger, with a Christmas bonus in the shape of a half month's pay, to show his appreciation of their exertions during the past year.

Telegraph Revenue.—The receipts on the telegraph service for the period between April 1st, 1885, and January 30th, 1886, amounted to £1,480,000 against £1,490,000 received from April 1st, 1884, and January 31st, 1886.

Imitation Telegrams.—The following notice has been issued by command of the late Postmaster-General: "Numerous advertisements having been issued in the form of fictitious telegrams, and many complaints having been received on the subject, the Postmaster-General thinks it right to call attention to the fact that the printing or circulation of fictitious telegram forms or envelopes, or of any document or form which is an imitation of a Post Office form, is an infringement of the sixth section of the Post Office (Protection) Act of 1884, and that any person acting in contravention of that section is liable to prosecution."

Recognition of Bravery.—Mr. H. Tomlinson, Demonstrator of Natural Philosophy at King's College, has recently been awarded the bronze medal and certificate of the Royal Humane Society for saving a young girl from drowning, at Seaford.

Overhead Wires.—The Metropolitan Board of Works has written to the local boards of the Metropolis in reference to the breakage and fall of overhead telephone and telegraph wires during the recent snowstorm, requesting information of any damage which has been caused in their respective districts.

At the last meeting of the Strand District Board of Works the Surveyor presented a report of the different overhead wires in the district which had given way in the late snowstorm. The list was not complete, but, so far as he was aware, there were no accidents—at least, he had heard of none. Mr. Lay suggested that a list of the different overhead wires in the district should be made out from time to time with a view to ascertaining as far as possible to whom they belonged. Mr. Jones (Metropolitan Board of Works) did not think much practical good could come of this. The great thing was to prevent, as far as possible, the granting permission for overhead wires, and he thought this should be urged on the Metropolitan Board, who should be asked to disallow overhead wires in future.

Why Electricity Should be Used.—One of the main boiler-pipes of an engine on the Dublin and Lucan steam tramline exploded on Tuesday morning at Chapelizod. The tram, it seems, had just stopped when the explosion took place. James Malherin, engine-driver, and Michael Casey, the stoker, were frightfully scalded. They were subsequently driven to Madame Stevens's Hospital. There were some passengers on the tram, but none sustained any injury.

Why not Electricity?—At a recent meeting of the Blackburn Town Council it was resolved to sanction the laying of nine miles of tramways in the borough, half to be worked by horses, and the other half, consisting of a trunk line from Blackburn to Church, by steam.

New York Underground Wire Commission.—The New York *Electrical Review* understands that the New York Subway Commission has finally reached a decision in the matter of recommending an underground system after examining the claims of over one hundred applicants.

Anglo-American Brush Corporation.—The report of this company, in another column, shows an improved state of affairs as regards the preparation of the accounts, as well as in the matter of business done, and we must congratulate the directors upon having, amid many difficulties, brought the company from the exceedingly precarious position it once occupied to one of comparative safe-standing. We venture to suggest, however, that they might with advantage and justice go yet further in the direction of depreciation, especially as regards the amounts under the heads of "Patents" and "Stock," which, in our opinion, are still vastly too high. In so far we deprecate the payment of a dividend, as misleading to the shareholders. A central generating station at Manchester is mentioned in the report, but no particulars respecting it are given; our curiosity is aroused as to the nature of this central station, and we should be glad to be informed of its locality and of the amount of business done in connection with it.

The Electric Lighting Act.—At a general meeting of the Electric Lighting Act Committee recently held at the offices of the Anglo-American Brush Electric Light Corporation, Belvedere Road, Lord Thurlow in the chair, a resolution was adopted on the motion of Viscount Anson, approving the action of the Executive, and expressing satisfaction at the announcement that Lord Rayleigh had, at the request of the Executive, agreed to introduce the Bill drafted by the Committee into the House of Lords.

The Kinetic Engineering Company.—This company has opened a branch depôt and show room at 117, Queen Victoria Street, E.C.

He Found It!—An explosion of gas shortly before eight on Saturday night was caused through seeking for an escape of gas with a light on the premises of Messrs. Steinway and Co., pianoforte manufacturers, at 17, Lower Seymour Street, Portman Square. An escape was detected, and a Mr. Henry Trenchman attempted to discover the source of leakage by means of a lighted candle. The result was a loud explosion which caused great damage to the lower part of the premises, and was followed by a slight outbreak of fire, quickly subdued. Mr. Trenchman was somewhat seriously burnt about the face and hands.

Electric Communication Between Vessels at Sea.—*Science* states that an experiment in the direction of securing communication between vessels at sea by means of electricity will be made at some time during the present week in the Chesapeake Bay. A board of naval officers has been detailed to witness the trial. They will be accompanied by Professor A. Graham Bell, who has long been interested in the subject, and who has himself experimented upon it.

Electric Locomotion.—At a meeting of the Elektrotechnischen Verein, held at Berlin on the 22nd of December, 1885, Herr J. Zacharias read a paper on electric locomotion, especially with regard to tramlines, and to which we have previously alluded. The chief subject of the lecture was Mr. Reckenzaun's electric tramcar. Opening the discussion, which followed the lecture, Prof. Dr. Foerster, after having conveyed the thanks of the meeting to the lecturer for his paper, which promised a real Christmas gift for electrotechnics, asked Mr. Reckenzaun, who was present, whether he had any remarks to offer. That gentleman stated that he had nothing to add, as the lecturer had placed everything in such a clear light; but that he was prepared to answer, at the conclusion of the meeting, any criticisms or questions affecting his invention. Dr. Werner Siemens said that there was no faith generally in the durability and commercial value of accumulators for electric locomotion, &c.; that, however, Mr. Reckenzaun does not share that unbelief, and that he has apparently succeeded in the construction of a practical secondary battery. It would be a great blessing to the development of electrotechnics if those secondary batteries prove reliable. Dr. Siemens further said that there are two bold features in Mr. Reckenzaun's undertaking: Firstly, his faith in the accumulator; and, secondly, the worm gearing he employs. As regards economy, Dr. Siemens agreed with Mr. Reckenzaun, that electrical traction is more economical than animal traction; the engine consumes coals, the horses consume oats, and of the two the latter commodity is the more expensive.

Forms of Electrical Conductors.—The self-induction of a flat copper conductor Prof. Hughes finds to be far less than that of a solid of circular section during the variable period. Even with a constant current, as in the stable period, he further adds, this form of conductor, as *first shown* by Prof. George Forbes, would, from its greater radiation, convey more current with less heating than a wire or rod of the same resistance. We have, on previous occasions, stated that the work of Prof. Forbes on this subject is simply an elaboration of the prior publications of the late Robert Sabine, and to this fact we would call the attention of Prof. Hughes. In an article to the REVIEW in January, 1883, the first, so far as we are aware, dealing with the loss occasioned by heat in electric light conductors, Mr. Sabine says:—"The best form would probably be a copper band which would present a large radiating surface."

Electric Tramway on Ryde Pier.—In accordance with a resolution passed a short time since at a general meeting of the Ryde (Isle of Wight) Pier Company, the tramway on Ryde Pier is in future to be worked by electricity, which, it is believed, will prove cheaper and more efficient than the present system, by which

horse-power is used. A 16 horse-power Otto engine, manufactured by Messrs. Crossley and Co., with all the latest improvements, including a self-starting apparatus, is being erected at the south end of the pier, while Messrs. Siemens and Co. are engaged in fitting up a most powerful dynamo machine to supply the motive power, which can be stored on the cars themselves. The Ryde Pier Company is to be congratulated on having thus adopted the electric mode of traction in preference to the cumbersome and inelegant wire-rope system, which, on the ground of economy, found favour among a certain number of the shareholders. The increasing traffic on Ryde Pier rendered the change necessary, and it is confidently believed that the novelty of the new departure will induce many visitors to the pier to ride in the trams who otherwise would walk. The improvement was referred to at the annual dinner of the *employés* of the Ryde Pier Company, held a few days ago under the presidency of Mr. George Garnett, C.E. (a member of the board of directors), when Mr. Conner, of the Isle of Wight Railway, said that the electric tramway showed great enterprise on the part of the directors. The shareholders would have great reason to be proud of it, for it would be the first electric tramway in the country. There existed a successful toy railway at Brighton, but this would be something more, and would attract visitors from all parts of the country. The Chairman said that the fact pointed out by Mr. Conner that this was the first real electric tramway in the country was well worthy of notice. Within a month he hoped to see an electric tramway travelling up and down the pier.

[We imagine that by the "country" is meant the Isle of Wight.—EDS. ELEC. REV.]

Professor Hughes on Self-Induction of an Electric Current.—There are several points in the admirable inaugural address of Prof. Hughes, which will no doubt be commented on in the discussion which is to take place on the 11th. As regards the experiments on the self-induction in wires of various diameters, it appears to have been overlooked that, as the battery power employed was preserved constant, the change in the diameter of the wires must have reduced the total resistance of the circuit, and consequently altered the current flowing through the wires; thus *two* conditions are altered which may possibly account to some extent for the form of the diagrammatic curves obtained. We would also suggest that the fact of iron being a magnetic and copper a diamagnetic metal, would account for the peculiarity noted as regards iron and copper rope, the iron strand being partially magnetically insulated from each other through the strands touching at points only, and that in the direction in which magnetism would become developed, *i.e.*, at right angles to the line of flow. The argument as regards lightning conductors deserves the careful notice of manufacturers engaged in the erection of the same.

An Important Invention.—It is stated that an American has been giving the matter of improvements in ships' compasses and steering gear some attention, and has patented a pneumatic-electric device by which a ship can do her own steering and keep her own course. There is an electric connection with the binnacle at the point toward which it is desired she should steer, and any deviation from this by the motion of the vessel brings the pneumatic gear into work and acts upon the rudder. The invention has already been tested on board a United States steamer with a successful result.

Edison Central Stations in America.—The 1,600-light central station of the Edison Company at New Bedford, Mass., was ready for starting up about the first week in February. The New England Wiring Company has fitted up this station with all the inside wires and the wiring of the poles, while the Edison Tube Works Company, of New York City, has attended to the underground work.

A Miners' Electric Lamp.—At the recent conference of the Miners' Union, Mr. Burt, M.P., the president, observed that two things were very desirable in the way of lessening the number of explosions. One was the provision of a good useful light, and the other the abolition of blasting by gunpowder in fiery mines. We read in the *Times* that the first of these conditions appears to be met by an apparatus which is self-contained and consists of a chloride of silver battery composed of three cells, each 6 in. high by 3 in. wide and 1 in. deep. The current produced supplies a small glow lamp, of German manufacture, which is placed in front of the metallic case containing the battery after the fashion of the bull's-eye of a police lantern. The lamp is well protected, and is provided with a reflector, so that a good light is thrown forwards. The light given by this lamp is stated to be of 3 candle-power, and to be capable of burning for nine hours, but this, as far as candle-power goes, is in excess of the requirement of the miner, so that smaller sizes are made. The cells are hermetically sealed, so that the lamp can be used at any angle without fear of loss of the liquid or extinction of the light as with the ordinary miners' oil lamp, than which the new one is said to cost much less for maintenance. Upon this point, remarks our contemporary, it is to be observed that when the power of the cells is exhausted there is no waste of the elements. The chloride of silver will have become converted into pure silver, and can be revivified by washing in a solution of nitric and hydrochloric acid. The lamp and the battery are both locked against the miner, who cannot interfere with either. The lamp can be hooked up in the ordinary way, or attached to the miner's belt. It has, says the *Times*, had the approval of one of our leading electricians, and of several mining authorities subject to being tested.

[We fancy we can here recognise an old friend in a new guise.—EDS. ELEC. REV.]

Domestic Electric Lighting.—Osmaston Manor, near Ashbourne, on the occasion of a ball given by Sir Andrew Barclay Walker, Bart., on the 19th ult., was for the first time lighted by the electric light. Sir A. B. Walker having decided to permanently light the house, arranged that the Liverpool Electric Supply Company should carry out this work. In addition to the permanent lighting, a temporary installation was made in the conservatory and large portable ball room, which was fixed on the lawn. Although the time available was exceedingly short, Messrs. Holmes and Vaudrey decided, as far as possible, to put down the plant permanently, and on the evening of the ball the whole of the ground floor and stairway landing were provided with the special fittings which had been made to suit the various rooms. In these rooms, and in the conservatory and ball room, were distributed 200 16-C.P. incandescent lamps, The engine, which was fixed in a shed built for the purpose, is a 20 horse-power compound, of Messrs. Marshall's well-known make. The plant is capable of supplying between 300 and 400 lights, and it is arranged for a complete and permanent installation of this number.

Relative Cost of Different Sources of Light.—Lecturing recently at Stafford on "Sources of Light," Prof. W. F. Barratt, F.R.S.E., of the Royal College of Sciences, Dublin, comparing the different illuminating agents in use at the present moment, said that for the same amount of light, gas cost 6d., the glow electric light 6d., and the arc 3d. Paraffin oil occupied a very high position as an illuminant in cheapness and undeleterious nature of waste products, but its disagreeable smell and the danger attending its use were against it. Electricity gave rise to no deleterious products at all, but the arc lamp gave a dazzling though flickering light, throwing intense shadows. The arc light was far less expensive than the glow light. In calculating the cost of providing the electric light for a house, the chief item was the interest on capital laid down in plant; the actual supply of electric energy

was the least of the items. For 200 lamps lighted 500 hours a year it was cheaper to have gas than the arc electric light. But in gas the chief cost was the consumption of gas, and when the number of hours a year in which the light burned was extended, the relative cost of the two systems was reversed. The great requisites for an artificial light were steadiness, accessibility, cheapness, safety, non-deleteriousness, and whiteness.

Gas not Infallible.—The *Globe* of the 1st inst. states that some excitement was caused in Skibbereen, county Cork, on Saturday night, owing to the gas suddenly going out. Doors were closed, as it was feared that the shops would be ransacked by marauders. The alarm was intensified by the twofold rumour of an explosion and conflagration in the gas house. Crowds rushed to the place to find that the large gasometer had given way. Candles had to be used until Sunday night, when the defect was remedied.

Secondary Battery Efficiency.—Mr. Bernard Drake writes to us as follows :—" I was reported to have said at the Society of Arts meeting, January 20th, that in the tests made at the Electrical Power Storage Company's works with the experimental tramcar, it was found that the efficiency in ampère hours was 75 per cent., and in watts 70 per cent., charging and discharging the cells considerably above the normal rate ; the figures I gave were 85 per cent. in ampère hours, and not 75 per cent. As the commercial efficiency of secondary batteries is commanding considerable attention, I trust you will find space for the above correction."

The Light of Other Days.—Mr. W. F. Thomas, the lessee of Covent Garden Theatre during the promenade concert season, thus expresses himself to Mr. F. R. Reeves, manager of the Jablochkoff Company :—" In reply to your enquiry respecting the electric lighting of Covent Garden Theatre during my promenade concert seasons, I have no hesitation in stating, after my experience of the Brush Company, in 1882, the Jablochkoff (old company), in 1883, the Maxim-Weston Company, in 1884, and the Jablochkoff (new company), 1885, that on both occasions your system has proved itself in this theatre more satisfactory and reliable than the others, and that both your arc and incandescent lighting here last year far excelled any previous attempts at lighting this theatre by electricity, and gave me great satisfaction. I would add my thanks to your Mr. Newington for his exertions in carrying out the lighting throughout." M. Riviere also states that the lighting during his tenure of office was Weldon, *i.e.*, done well.

OFFICIAL RETURNS OF ELECTRICAL COMPANIES

Continental Etéve Engine Company, Limited.—An agreement dated 30th ult., and filed with the documents of this company on the 1st inst., provides for the allotment to Jean Andre de Braam and Eugene Etéve 400,000 fully paid shares in consideration of the sale and transfer of certain letters patent referred to in an agreement of 25th September, 1885.

London and Globe Telephone and Maintenance, Company, Limited.—The annual return of this company, made up to the 19th of August, 1885, was filed on the 29th ult. The nominal capital is £600,000 in £1 shares. 140,007 shares have been allotted and the full amount has been called thereon. The calls paid amount to £56,392 and unpaid to £945, and 82,670 shares are considered fully paid up.

Single Wire Multiple Telephone Company, Limited.—The annual return of this company, made up to the 12th ult., was filed on the 28th ult. The nominal capital is £5,000 in £10 shares. 194 shares have been taken up, and the full amount has been called and paid thereon.

United Telephone Company of the River Plate, Limited.—An extraordinary general meeting of this company was held at 131, Wool Exchange, Coleman Street, on the 28th December, when it was resolved "That the articles of association be altered as follows :—In article 72 the expression 'a member or' shall be substituted for the expression 'at least five.'" The resolution was confirmed at a meeting on the 12th ult., and duly filed on the 1st. The alterations bear reference to the right of members holding 1,000 shares to demand a poll.

New Electro-Amalgamator Company, Limited.—The statutory return of this company, made up to the 21st ult., was filed on the 28th ult. The nominal capital is £6,000 in £1 shares. 4,565 have been taken up, and the full amount has been called thereon. The calls paid amount to £3,339 and unpaid to £499. 727 shares are considered as fully paid.

CITY NOTES, REPORTS, MEETINGS, &c.

Cuba Submarine Telegraph Company, Limited.

THE half-yearly general meeting of this company was held at the offices, 61, Old Broad Street, E.C., on Wednesday, Mr. J. de Mancha presiding.

Mr. Scott, the Secretary, having read the notice convening the meeting,

The Chairman said they would see by the report that after providing for the portion due for the 1881 cable and other expenses, there was a sum of £8,641 for division. Taking into consideration the depression of trade all over the world, he thought they might consider the accounts satisfactory. Unfortunately they had had to suffer from the depression, for their business had declined somewhat, 500 less telegrams having been transmitted in the past six months, as compared with the corresponding six months of the previous year, decreasing their income by about £1,000. With regard to the paragraph in the report relating to the proposed Halifax-Bermuda cable, when they first saw the advertisement issued by the Government they thought it desirable to communicate with the friends connected with their line, with the view of preparing a scheme, and, if thought desirable, making an offer for laying the cable. They found, however, that some of their colleagues would not enter into the matter. At one time they thought that they and their friends in other companies might contribute together for the establishment of a company which might be formed to lay the cable, and then to come to the shareholders and ask them to take shares in the new company. But after due consideration they thought it advisable not to tender at all. The difficulties were very great; from the report that the *Challenger* had made to the Government, it was found that the depth was very great indeed, that in some cases the bottom was very rocky and very bad for laying down a cable, and that they would have had in some cases to go down to four miles, while, in case of any misfortune, it would be almost impossible to get up the cable again. They wrote to the Government, representing the injustice to this company, after it had been so many years in existence and had spent a large amount of money in keeping up communication with the West Indies, of subsidising another company. To that letter the Colonial Office replied that the Government could not depart from its decision, arrived at on grounds of public policy, to subsidise a cable between Halifax, Bermuda, and Jamaica. They took no further action, except to endeavour to ascertain whether other companies had offered to lay the cable. They wrote again to the Government, but had received no reply, and he supposed that with the elections and the probable change of Government, the matter had been allowed to drop. He hoped the line would not be laid, and that if it was some arrangement might be made whereby this company would not be prejudiced. Following the desire of some of the shareholders, the directors were reducing the amounts in some of the banks; but in these times of cheap money it was difficult to get 5 per cent., and some of the oldest and best banks in which they deposited had informed them that they could no longer pay 5 per cent., and offered 4½ per cent. interest. He moved that the report and accounts be adopted.

Mr. Low seconded.

Mr. D. W. Greig congratulated the directors upon their success in keeping the company in such a good state, and then called attention to an apparent diminution in the reserve fund. He also reminded them that there were two classes of shares, the 10 per cent. and the ordinary, and said it would be a great thing if they could by any possibility devise some means whereby both might sail in one boat.

Mr. Goddard suggested that the company should gradually purchase the preference shares, or as many as possible, in the market.

Mr. Griffith strongly condemned the proposed action of the Government in laying down a cable from Halifax to Bermuda for which there was no military necessity and which could not be commercially successful. He pointed out that European telegrams could not be sent over that cable, because the Anglo-American Company was under agreement with the Western Union Company, over whose land lines all such traffic must go. Then this company was in agreement with the West India and Panama Telegraph Company, and the latter sent all messages from the West Indies through the Cuban cables, so that the new line would be ostracised altogether. He was not without hope that the scheme would be abandoned.

The Chairman, replying to the shareholders' remarks, explained that the reserve fund had not really been decreased, but there had been a transposition of figures upon the suggestion of the auditor. With regard to the preference shares, the question had been very much before them, but he did not think they had power to act upon Mr. Goddard's suggestion. Most of the preference shares were held by widows and others who liked to have their money secure, and it would be difficult to get them to consent to any change. If they paid 10 per cent. for five years upon the ordinary shares they might possibly, by paying a little bonus, get them to come in upon equal terms with the other shareholders.

Mr. Griffith said that, as a question of strict law, companies were not usually allowed to invest in their own shares, the objection being that it diminished the capital which the outside creditors could fall back upon. But it would be possible, he thought, to pass a resolution giving the board powers to buy up gradually. It was a matter of doubtful wisdom, however, and he could not say whether it would be expedient, or generally for the benefit of the company.

The resolution for the adoption of the report was then put and carried unanimously.

The Chairman next moved the declaration of dividends of 10 per cent. per annum, subject to income-tax, upon the preference shares, and of 7 per cent., free of income-tax, on the ordinary shares.

Mr. Low seconded, and the motion was carried.

Mr. Goddard moved a vote of thanks to the directors, which was accorded and acknowledged, and the meeting terminated.

Maxim-Weston Electric Company, Limited.

AN extraordinary general meeting of the shareholders of this company was held at the Cannon Street Hotel on Monday, under the presidency of Mr. Hugh Watt, M.P., for the purpose of confirming resolutions passed at a meeting reported in our last issue.

The Chairman said it was not necessary to repeat the arguments which he used when the resolutions were first placed before the shareholders as to the reasons which induced the board to arrive at the conclusion as to the desirability of reducing the amount, for virtually it was reducing the amount, to the debit of patents account, by reducing the capital of the company to 5s. per share. He hoped he made it clear on the last occasion that the directors considered the company, in view of existing circumstances, over-weighted by an amount of capital which, as far as the present board was concerned, they had never possessed. In his opinion no patents at the present moment were equal to those possessed by this company, but after a great deal of consideration he thought it would be to the interests of the shareholders to reduce to 5s. per share, thus bringing the patent account to something like £50,000 less than last year. One reason was the existing state of the electrical market. Nothing of an illusory character had been entertained by the company; they had taken an entirely commercial view of things, and endeavoured, as far as possible, to conduct the business as though it were a private enterprise. The result, in the opinion of the directors, was satisfactory; and they believed, when the reduction of the capital was completed, they would be able to greatly improve their position. Another reason for the change was the opinion of the solicitor and of counsel that it would have been impossible for them to have declared a dividend for the past year. The shareholders last year were good enough to express an opinion, in opposition to his recommendation to pay a dividend, as to the advisability of retaining the money as working capital. He would ask now for an equal degree of magnanimity, and that they would give some expression of opinion as to their wishes in regard to a dividend. He thought they ought to pay something. It was true the present board had not been in office ever since the floating of the original Electric Light and Power Company, but the shareholders who, like himself, invested at a high premium, naturally wanted some return for their money after some few years' delay. He then moved the confirmation of the resolution, "That the capital of the company be reduced by £62,500 by cancelling paid-up capital unrepresented by available assets (being patents over-estimated in value) to the extent of 5s. per share upon each of the 250,000 shares which have been issued and are now outstanding."

Mr. John Brown, a director, seconded this motion, which was carried without dissent.

The Chairman then moved the confirmation of the second resolution, "That the capital of the company be further reduced by £62,500 by reducing the nominal amount of the remaining 250,000 shares of the company's capital from 10s. to 5s. each, thereby leaving the nominal capital of the company £125,000 divided into 500,000 shares of 5s. each.

Mr. Louis Swaby, another director, seconded this resolution, which also was unanimously agreed to.

The Chairman repeated his desire to hear the opinions of the shareholders as to the amount of the dividend that should be declared, and gave a short statement showing the financial position of the company. The board deemed it advisable to pass the sum of £3,606 5s. to a general reserve account, being induced to do that by the fact that the late board had left, among other legacies, a probable bad debt of £1,700. After allowing for this sum, the balance remaining to the credit of the profit and loss account as at December 31st, 1885, was £5,285.

Mr. Griffith said after what the Chairman had told them, he thought all the shareholders would be of his opinion, and would willingly assent to the declaration of a dividend of 7½ per cent.

This was concurred in by several other shareholders, and the Chairman accepted the opinions expressed as a recommendation to guide the board in preparing for the annual meeting.

Mr. Griffith moved a vote of thanks to the Chairman and directors, which was heartily accorded, and in replying,

Mr. Watt made reference to the Electric Lighting Act of 1882, which had done much to retard electric lighting, the Lancashire Maxim-Weston Company having been entirely ruined by that Act, and spoke hopefully as to the prospects of securing an amelioration of the conditions it contained. The Bill of which he had given notice in Parliament had brought him letters from various gentlemen who were anxious to back his Bill and to assist him as far as possible.

Anglo-American Brush Electric Light Corporation, Limited.

THE report of the directors for the year ended 31st December, 1885, states that the general prospects of the electric lighting industry have continued to improve, and although the advance has not been so great as was hoped for, the business and profits of the corporation have sufficiently increased to justify, in the opinion of the board, the distribution of a dividend.

The range of the business of the corporation has, during the past year, been largely extended. As a result of the absorption of the Great Western and Brush Midland Companies, reported on last year, important centres have been secured in South Wales and the West of England, and there is no reason to doubt that when the present legislative obstacles to central station lighting have been removed, the corporation will benefit by the connections which have been established. An important station has also been acquired at Manchester, while a branch office has been opened at Edinburgh.

The Continental work of the corporation has again been of a very encouraging character, and the agency for the German Empire, organised about 18 months back, especially promises further good results, the corporation having lately entered into an arrangement for the establishment of a central lighting station in an important part of Berlin. In view of the magnitude and increasing importance of the foreign interests and relations of the corporation, the board have recognised the necessity of having a representative abroad, and they have appointed Mr. Frank Wynne, who for the last two years held the post of general manager in England, to superintend the Continental work of the corporation.

The corporation are able to show a satisfactory record of practical work done during the year. In addition to the share of Government contracts for the supply of electric lighting apparatus which the corporation continue to receive, several profitable and interesting installations of the electric light have been carried out in docks, railway stations, collieries, factories, and private houses: also, as a somewhat new departure, a very successful installation has been completed upon the Duke of Bedford's yacht *Northumbria*, and upon others of a similar class. The International Inventions Exhibition afforded the corporation a favourable opportunity of bringing to the notice of the public the merits of their numerous patents, the commercial and scientific value of which was recognised by the award of a gold medal.

The superiority of the manufactures of the corporation has been fully maintained, and the fact of the corporation being the only firm in this country able to meet by their own manufactures the demand for both arc and incandescence apparatus, gives them a manifest advantage in the competition for business. The corporation may in a large measure take credit (by the construction and form of the "Victoria" dynamo) for the introduction of slow speeds for both dynamos and engines, whereby the general lighting of ships has been furthered. The attention of the corporation has also been directed to the production of motors to work in connection with Brush machines, and success in this branch of electrical work, the demand for which in the future is likely to be considerable, may be considered as assured.

In the last annual report the directors had the satisfaction of congratulating the shareholders upon the freedom of the corporation from litigation, and this immunity has happily continued during the past year. At the same time they intimated that they would regard it as their first duty to take such steps, with a view to the maintenance and protection of the valuable patent rights of the corporation, as might from time to time seem necessary. Since then the board have deemed it their duty to procure the recognition by other manufacturers of the rights of the corporation in respect of their patents and improvements, and the directors are glad to be able to report that the results of the

steps taken have been satisfactory to the interests of the proprietary.

The shareholders have already been made acquainted by the half-yearly report issued in July last with the progress which has been made in the direction of obtaining an amendment of the Electric Lighting Act. The general election which has since taken place has undoubtedly strengthened the position then taken up, and abundant proof has been afforded of the increasing interest taken by the public in this question, and of their appreciation of the necessity for further legislation in this matter. It is under these circumstances a great source of congratulation to your directors that the draft Bill prepared last year by the Electric Lighting Committee, which held their meetings in your offices, has been taken as the basis of a measure to be shortly submitted to the House of Lords by Lord Rayleigh.

It will be seen from the balance sheet that the called-up capital stands at £190,174. This is a diminution upon the figure at which capital stood last year of £795, due to the maximum number of shares to be issued to the members of the Great Western and Brush Midland Companies having been reduced by 159 shares in consequence of arrangements, advantageous to the corporation, made with some of the shareholders of the Midland Company, by which they relinquished their claim to these shares in consideration of the liquidators accepting the difference only between the amounts of the call due by them and the value of the shares in the corporation to which they would have become entitled upon paying the call in full.

The total amount owing by the corporation to creditors is £6,233 17s. 2d., as against £3,726 6s. 4d. in 1884, while the good debts due to the corporation, together with cash at bankers, amount to £39,563 1s. 2d., as against £30,102 0s. 10d. last year, a comparison which will serve to indicate to some extent the improvement which has been effected in the financial position of the corporation during the year.

The contra items representing shares held by the corporation in other companies and provision against same have been reduced by £36,000, the amount of the shares which the corporation held in the Anglo-Spanish Company. These shares have been relinquished by the corporation in consideration of that company paying £500 in cash, and re-assigning the Brush and Lane Fox patents for Spain to the corporation. This leaves the disposal of the Spanish patents again in the hands of the corporation, and indications are not wanting to justify the hopes of satisfactory and profitable business spring up in this direction.

The patents and goodwill account has been increased by £12,536 6s. 4d., about £11,000 of which represents the consideration paid in shares of the corporation to the Great Western and Brush Midland companies for the surrender of their licenses and the goodwill of their business. The reason for the amount of this consideration being larger than the estimate contained in the last annual report is, that some of the other assets transferred by these companies to the corporation have, in consequence of the reduced valuation of the plant and stores of the corporation, been merged into the books at figures much below the original and otherwise perfectly justifiable estimates. The other items making up the increase of patents and goodwill account represent the cost of maintaining the English and foreign patents, and of developing and securing patent protection for several recent inventions, adding very materially to the aggregate value of the property in patents held by the corporation. It should also be remarked that the value of the asset represented by this account has been still further enhanced by, though the figure has not been augmented in respect of, the reversion of the Spanish patents to the corporation referred to in the previous paragraph, and the directors entertain the conviction that the patents held by the corporation stand in the accounts at a figure so low as to be out of all proportion to their value—a circumstance that has of course a most favourable bearing on the value of the share capital of the corporation, and renders it unnecessary to reduce the amount at which patents now stand in the books.

The property account shows an increase upon last year's figure of £11,786 8s. 10d., which is mainly due to the acquisition of the freehold and leasehold land and buildings and plant of the Great Western and Brush Midland Companies at Cardiff, Bristol, Cleethorpes, and other places, and to the purchase of the Central Generating Station at Manchester, already referred to. The stock account, which stands at £69,626 13s. 7d., shows no material alteration in the aggregate value of the stock on hand (taken at the valuation mentioned in the last annual report), stores and goods in course of manufacture.

The amount of £1,699 11s. 6d. standing to the credit of assets realisation account represents the residue of the assets of the Great Western and Brush Midland Companies still to be transferred to the corporation by the liquidators. Should the assets still in the hands of the latter not realise this amount the deficiency will be added to the cost of the goodwill &c., of these companies, in accordance with the principle laid down in the last annual report.

The profit and loss account shows a gross profit of £20,935 9s. 3d. after providing for bad and doubtful debts, and including the £500 received from the Anglo-Spanish Company, mentioned in paragraph 11. After deducting all standing charges and expenses there remains a balance to credit of profit and loss account, including the balance of £1,627 15s. 4d. brought forward from last year, of £6,728 6s. 8d. The standing charges, it will be noted, show an increase in the aggregate of £1,140 17s. 2d. This is due partly to the higher premiums now generally demanded by fire insurance companies, to additional advertising, travelling, and to such other expenses as are directly attributable to the larger volume of business transacted by the corporation during the year, and to the steps taken in furtherance of increased future developments.

The board recommend that £2,000 be applied to the reduction of properties and plant account, that £3,803 9s. 7d. be applied to the payment of a dividend at the rate of 2 per cent. per annum on the whole share capital of the corporation, and that the balance of £924 17s. 1d. be carried forward to next account.

The directors consider that there is good ground for encouragement in the prospects of business during the current year. The corporation have already secured important contracts for lighting portions of the various exhibitions to be held during the summer, and there is reason to hope that the negotiations which have been carried on during the past two years with the Corporation of the City of London for lighting an extended area are now approaching a satisfactory termination. The directors also look for an accession of business to the recent adoption by the corporation of the policy of supplying and erecting electric lighting apparatus upon the purchase hire system, by which payments may be extended over a period of three years.

Balance-sheet:—Dr.—To capital, £190,174; to creditors, £6,233 17s. 2d.; to provision for shares in other companies, £14,000; to balance of profit and loss account, £6,728 6s. 8d.; total, £217,136 3s. 10d. Cr.—By patents, £39,712 19s. 3d.; by property, £51,933 18s. 4d.; by stock, £69,626 13s. 7d.; by debtors, £32,969 7s. 2d.; by cash, £6,593 14s.; by shares and debentures in subsidiary and other companies, £14,600; by assets realisation account, being balance of assets still to be dealt with by the liquidators of the Great Western and Brush Midland Electric Light Companies, £1,699 11s. 6d.; total, £217,136 3s. 10d.

Anglo-American Telegraph Company, Limited.

THE report of the directors to be presented at the meeting of the proprietors, to-day (Friday), states that the total receipts from the 1st July to the 31st December, 1885, including a balance of £5,343 5s. 7d. brought forward from the last account, amount to £155,799 3s. 5d. The traffic receipts show a decrease as compared with the corresponding period of last year of £93,926, consequent upon competition, a reduced tariff, and continued depression of trade between Europe and America.

The total expenses of the half-year, including repair of cables, &c., as shown by the revenue account, amount to £49,202 9s. 10d.

The directors, under the powers conferred upon them by the articles of association, have, before declaring the nett profits, set apart the sum of £50,000 to the renewal fund, leaving a balance of £56,596 13s. 7d.

Interim dividends of 5s. per cent. on the ordinary stock, and 10s. per cent. on the preferred stock, were paid on the 1st November last, absorbing £17,500, leaving a balance of £39,096 13s. 7d. out of which the directors recommend the proprietors to declare final dividends of 10s. per cent. on the ordinary stock, and £1 per cent. on the preferred stock, amounting to £35,000, making a total distribution for the year ended the 31st December, 1885, of £1 5s. per cent. on the ordinary stock, and £2 10s. per cent. on the preferred stock, leaving a balance of £4,096 13s. 7d. to be carried forward to the next account.

The company's repairing ss. *Minia* has been engaged during a portion of the past half-year in the repair of the Brest, Duxbury, Placentia and Island Cove cables. She has also effected the repairs of two main cables belonging to the Western Union Telegraph Company, and of the main and short sections of the Direct United States Cable Company, having been chartered to those companies for the purpose.

The company's system of cables and land wires is in good working order.

The competition with the Commercial Cable Company (Mackay-Bennett Cables) still continues. The loss caused by the reduction of rate from 2s. to 1s. 8d., estimated in the report of the directors dated 29th January, 1885, at £170,000 a year, has amounted to more than that sum, as it has not been followed by any augmentation of the traffic.

Branch offices have been opened during the past year, at the expense of the Associated Cable Companies, at Glasgow, Bristol, and Havre.

Since the report was printed a circular has been issued by Mr. Jeremiah Stockdale, hon. sec. of a "Shareholders' Association" recently formed at a meeting in London, at which about 25 persons were present.

The only communication made by the association to the Board is contained in the annexed letter of the 21st instant, to which a reply was sent on the 23rd, copy of which is also annexed.

From this correspondence it will be seen that Mr. Stockdale was distinctly informed that the resolution, which he now asks the proprietors to support by their proxies, cannot legally be put to, or voted upon, at the meeting on the 5th February.

The directors are advised by eminent counsel that no resolution of a general meeting can release directors from the duty expresely laid upon them by the articles of association to exercise their own judgment upon the amount to be set apart for the renewal of the company's cables. Under these circumstances the directors do not think it needful, even if there were time, to answer the statements in Mr. Stockdale's circular.

The views of the directors on the subject were explained in the last report, and they see no reason to alter the opinions therein

expressed, and which were then endorsed by the votes of an enormous majority of the proprietors.

If the Shareholders' Association accept the suggestion made to them to convene an extraordinary meeting, every facility will be afforded for the full discussion of the question.

The correspondence alluded to consisted of a letter from Mr. Stockdale to the directors giving notice that at the half-yearly meeting, Mr. Thomas Smith, of York, would move this resolution: —"That with the exception of accruing interest, no further addition be made to the so called renewal fund, as from 1st January, 1886"; and the reply of the secretary in the terms stated.

Telephone Company of Austria, Limited.

THE report of the directors of this company for the period since the formation of the company to the 30th of June, 1885, states that as this is the first report issued by the company the board deem it advisable to submit to the shareholders a few facts which will place the position of the company more clearly before them. They remind them that in July, 1884, the affairs of the company had reached such a point that it became a question whether the concessions would not be forfeited. By vigorous efforts a thorough reorganisation was commenced by the present board, capital found to continue the installations, arrangements concluded with the concessionaires in Austria, debentures issued for the debt which has been incurred, and the whole management thoroughly examined into. The result of this policy is stated to have been very satisfactory. On the 30th of June, 1884, the number of subscribers to the exchange and private lines was 626, the annual income being 51,579 fl. On the 30th of June, 1885, these totals were 1,012 and 86,303 fl. respectively, and on the 31st of December, 1885, they were 1,246 and 102,831 fl. respectively. To make the period of accounts correspond with the financial year of the parent company (the Consolidated Telephone Construction and Maintenance Company), and as required by the Austrian Government, it is proposed to issue a further balance sheet in May next, comprising the accounts of the company for the nine months from July 1st, 1885, to March 31st, 1886; the latter date will in future be the end of the company's financial year, and accounts, with the directors' report, will be issued in May following.

The India Rubber, Gutta Percha and Telegraph Works Company, Limited.—Subject to audit, the company's accounts to 31st December last show the following result:—Brought forward from 1884, £40,070; premium on new shares issued in 1885, £52,394; net profit for 1885, £65,862—£158,326; less interim dividend paid in July, 1885, 5 per cent., £20,779. Total, £137,547. The directors have to-day resolved as follows:—To add to reserve fund (including premium on new shares), £55,000; to recommend a dividend of 10 per cent. (making 15 per cent. for 1885), £41,600; to carry forward to 1886, £40,947. Total, £137,547.

The National Telephone Company, Limited.—The directors have resolved to declare an interim dividend for the six months ending December 31st last at the rate of six per cent. per annum on the first and second preference shares, and at the rate of three per cent. (as against two per cent. for the corresponding period last year) on the ordinary shares, £2,685 being carried forward. The unaccrued revenue carried forward to the credit of next account amounts to £34,058, as against £29,995 last year.

Submarine Telegraph Company, Limited.—The accounts for the half year ending December 31st last, submitted to the board, show a balance, subject to audit, which enables the directors, after adding 15 per cent. of the gross receipts to the reserve fund, to recommend a dividend at the rate of 14½ per cent. per annum.

Edwin Fox and Company, Limited.—Applications are invited for 2,458 shares in this company, which was formed in 1882 to take over the business of that firm known as the Magnetic Telegraph Wire Works, at Millwall. The capital is £50,000 in £10 shares, of which 2,542 have already been taken.

The Maxim-Weston Electric Company, Limited.—The directors have decided to pass a sum of £3,600 to a general reserve account, and to recommend a dividend of 7½ per cent. for the past year, carrying forward a balance of about £600 to next year.

Eastern Telegraph Company, Limited.—This company notifies that the coupons on its 5 per cent. debentures, due on the 14th inst., will be paid at the banking-house of Messrs. Glyn, Mills, Currie & Co.

TRAFFIC RECEIPTS.

The Cuba Submarine Telegraph Company, Limited. The number of messages passing over the lines of this company during the month of January was 3,485, estimated to produce £2,850, against 3,555 messages, producing £3,013 in the corresponding month of last year. The receipts for the month of October, estimated at £2,100, realised £2,156.

The West India and Panama Telegraph Company, Limited. The estimated receipts for the half-month ended the 31st January are £2,799, as compared with £2,766 in the corresponding period of 1885. The October receipts estimated at £3,894, realised £3,940.

The Western and Brazilian Telegraph Company, Limited. The receipts for the week ending January 29th were £2,438, after deducting the fifth of the gross receipts payable to the London Platino-Brazilian Telegraph Company, Limited.

The Direct Spanish Telegraph Company, Limited. The estimated receipts for the month of January were £1,686, against £1,756 in the corresponding period of last year.

PROCEEDINGS OF SOCIETIES.

The Society of Telegraph-Engineers and Electricians.

THE first ordinary general meeting for the year of this society was held on Thursday, January 28th, Mr. C. E. SPAGNOLETTI, Past-President, in the chair. The ordinary formal business of the meeting having been concluded, the new President for the year, Prof. D. E. HUGHES, F.R.S., read his inaugural address as follows:—

Before commencing the subject of my address this evening, I desire to express my sincere thanks to the members of the Society of Telegraph-Engineers and Electricians for the great honour they have conferred on me by electing me as their president, and to assure them that I will do all in my power to aid and promote the interests of our society, which are those of applied science in one of its highest branches.

It is the custom in our society, that the elected president should open the session by an address containing a general review of the present state of electrical science, or researches in some special branch which may be of interest. I have chosen the latter, as it enables me to present to you some researches which I have not yet published, and I propose to present these in the form of a paper rather than an address, in order to allow our members the opportunity of a full discussion on the subject, which I hope may bring forth many new facts in their possession.

The subject which I have chosen is—

THE SELF-INDUCTION OF AN ELECTRIC CURRENT IN RELATION TO THE NATURE AND FORM OF ITS CONDUCTOR.

Induced or secondary currents in a near but independent circuit were discovered by Faraday in 1831; and the phenomenon of the self-induction of an electric current in its own wire was observed by Henry in 1832, and traced to its cause in 1834 by Faraday, who proved that on sending a current through a wire a momentary induced current in the opposite direction is evoked in its own wire; also that, on the cessation of the primary current, a second induced or "*extra current*" is excited in the direction of the primary. The effect is greatly augmented when the wire forms a coil, as we then have in addition the reaction of superposed currents; but the effect exists to a great extent even when the wire forms but a single loop, or a straight wire with the earth forming the returning portion of the loop, as in all telegraph lines.

It has been generally supposed that the nature or the molecular condition of the metal through which the primary current passed exerted no influence upon the extra currents except that due to its resistance. I have previously pointed out* that for induced currents "the rapidity of discharge has no direct relation with the electrical conductivity of the metal, for copper is much slower than zinc, and they are both superior to iron." This led me to make a study of these extra currents, for which purpose I constructed a special induction bridge, in order to measure both the primary and its extra currents separately at the instant of action.

INDUCTION BRIDGE.

This instrument is a combination of a portion of my "induction balance," with a "Wheatstone bridge." The resistance of the wire is measured and balanced by the bridge; the induced or extra currents are measured and reduced to zero by an equal opposed induced current from the induction balance.

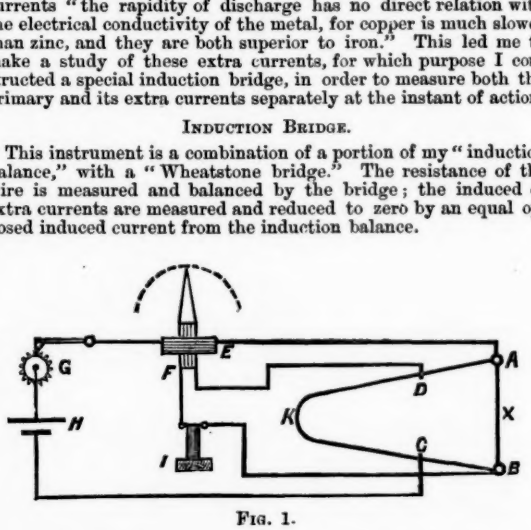


FIG. 1.

The above diagram shows the electrical communications. The bridge consists of a single German silver wire (0·25 mm. diameter, 1 metre in length, of 4 ohms resistance) running from A to K, returning to B. The wire is stretched and sustained upon two wooden arms articulated at K, by means of which the terminals, A, B, can be more or less separated as desired. The wire to be tested, X, is joined at A and B, thus completing the closed circuit of the bridge.

The external communications are shown, A being connected to the primary coil of the sonometer, E, and through it to the spring of the interruptor or rheotome, G, the interrupting wheel being connected to the battery, H, and thence to the bridge at C. The wire from B passes through the telephone, I, to the secondary coil, F, returning to D.

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* "Induction Current Balance," *Proc. Roy. Soc.*, vol. xxix., p. 56, 1879; "Molecular Electro-magnetic Induction," *Proc. Roy. Soc.*, March 7th, 1881.

Great care has to be taken in the construction of the bridge, so that it shall be as free as possible from induced or extra currents; and for this reason we cannot employ or introduce resistance coils. The resistance of the wire, X, is balanced by sliding the communications, D and C. It is evident that if all the arms of this bridge are equal in resistance and inductive capacity, there will be silence on the telephone; but if A, B be slightly stronger or weaker in inductive capacity, then we may be able to balance its resistance, but not its induction, as we shall then have a slight or a loud continuous sound due to the differential extra currents in the arm, A, B. These are compensated by the introduction in the circuit of the telephone of an equivalent but opposed induced current from the secondary coil of the sonometer, F, the degree of angle through which this coil has turned to produce silence being the degree of force of the extra current. The induction sonometer* consists of two coils only, one of which is smaller and turns freely in the centre of the outside coil. The exterior coil being stationary, the centre coil turns upon an axle by means of a long (20 cm.) arm, or pointer, the point of which moves over a graduated arc or circle. Whenever the axis of the interior coil is perpendicular to the exterior coil no induction takes place, and we have a perfect zero; by turning the interior coil through any degree we have a current proportional to this angle, and in the direction in which it is turned. The value of the induction current for each sonometric degree was $\frac{1}{1500}$ of the primary current which passed through the wire under observation, the latter being variable at will from ·001 to ·250 ampère. There is also a reversing key (not shown in the diagram), in order to place the interruptor on the telephone circuit and close the battery current from H to A; the conditions then being the usual method of testing, except using the telephone in place of a galvanometer—a well-known method. The telephone, being exceedingly sensitive and rapid, is most suitable, whilst a galvanometer would be too slow, and its use, in fact, impossible for the researches I have been making.

Numerous details have been necessarily omitted in this rough sketch of the instrument. Suffice it to say that it is perfectly adapted for the object sought, viz., the investigation and measurement of the self-induction which takes place in all wires.

By all previous methods the measurement of the resistance of a wire is taken when the current has been already some time in action, or, to use an expression of M. Gaugain, when the electricity has arrived at its "stable period." In telegraphy, electric lighting, and all applications using rapid electrical changes, another period has to be considered, viz., that during the rise and fall of the current; this he named "the variable period," and it is in this period that all the phenomena of induction take place.

To observe the *stable* period, the current is continuously passed through the bridge (and consequently through the wire under observation), and the interruptor being placed in the telephone circuit allows us to find the exact resistance of the wire, free from all induction or change in the wire itself.

To observe the *variable* period, the interruptor or rheotome (making at will from 10 to 100 contacts per second) is placed on the battery circuit, the telephone being joined as shown in the diagram.

By means of a switch or a reversing key these changes are made as rapidly and often as desired.

If there were no static or self-induction, no loss of time, or change of resistance, then the result from these two periods would be equal; but this is never the case, for we find that when the resistance is balanced to a perfect zero for the stable period, loud sounds are given out in the variable period, requiring a fresh adjustment or balancing of the resistance of the wire, as well as a compensating opposing induction current from the sonometer to balance the self-induction. If we balance the resistance or the extra currents alone there is no possible zero, but when both are compensated we find at once a perfect zero for the resistance of the wire, and for its extra currents.

Inductive Capacity of Metals.

The results of the following experiments prove that the force and duration of the extra currents depend upon the kind of metal employed as a conductor, its molecular condition, and the form given to the conductor, independent of its resistance or the electromotive force of the primary current. The increase of force by increased length is proportional to the length of wire less its additional resistance, but with wires of the same length increased cross section or diminished resistance does not produce a corresponding increase in the electromotive force of the extra currents.

The time of charge and discharge of the wire is independent of the electromotive force of the extra currents; for, if we compare currents of equal electromotive force obtained from copper and iron, it will be found that the duration of these currents in wires of 1 mm. diameter will be seven times slower in iron than in copper, and a still greater difference will be found in larger wires. The longest or slowest charge and discharge take place in the purest soft iron, and have a constant ratio of increase with increased diameter of the wire; my experiments giving for wires of double the previous section, or for wires of four times less resistance, a mean increase of three times its previous duration.

* *Comptes Rendus de l'Académie des Sciences*, Paris, December 30th, 1878, and Jauuary 20th, 1879; *Proc. Roy. Soc.*, vol. xxxi., p. 527, 1881.

The electromotive force of the extra current in different metals will be seen in the following table, and in order that the values obtained from the sonometer may be clearly understood I have reduced the results to comparative values.

The table of values were obtained on wires of similar length, having been repeated on a similar series of lengths ranging from 10 cm. to 5 metres. The instrument is sufficiently sensitive for pieces only 10 cm. in length, and the results from the short lengths were as pronounced and accurate as those for greater lengths. I may add that the instrument shows no effects or traces of static charge for the lengths mentioned.

Table I.

Wires 1 mm. in Diameter, 30 cm. in Length.

Soft Swedish iron ...	100	Copper	20
Soft puddled iron ...	78	Brass	13
Swedish iron, not softened	55	Zinc*	12
Soft cast steel	41	Lead	10
Nickel*	34	German silver	7
Hardened cast steel ...	28	Mercury*	2
Cobalt*	24	Carbon*	1

* Being unable to procure wires of these metals, they were tested in the form of strips, and compared with similar strips of copper. Mercury was in a glass tube 2 mm. in diameter; carbon tested in the form of electric light carbon from 3 mm. to 10 mm.

The above table is only true for wires of 1 mm. diameter, as the effect depends on the size of the wire in relation to the nature of the metal. In soft Swedish iron a diminution in the electromotive force of the extra currents takes place with each increase in its section, and this has been partially foreseen by Maxwell,* who said: "The electromotive force arising from the induction of the current on itself is different in different parts of the section of the wire, being in general a function of the distance from the axis of the wire as well as time."

From this I expected that the increase (? decrease.—Eds. Elec. Rev.) of electromotive force by an increased section would not increase directly as its sectional increase; but I was not prepared to find, as my experiments prove, that after a certain maximum diameter of wire has been reached a marked decrease in electromotive force takes place with each further sectional increase, and that this maximum is variable with each metal.

The diagram shows a rapid rise of force in soft iron from an extremely fine wire of 0·10 mm. section to a maximum at 1 mm., from which point there is a slow but continued decrease of force with each increase in the size of the wire, until at the comparatively great diameter of wire of 10 mm. the force is but a fraction more than in the extremely fine wire.

Hard Swedish iron has a less initial force in the fine wire, and does not arrive at its maximum until the wire has 3 mm. diameter, being then nearly of the same force as soft iron of the same diameter; the fall from this point is somewhat similar, but less than soft iron unt'l at 8 and 10 mm.; soft and hard iron have absolutely the same values.

A curious change of values at different diameters will be seen in copper and brass. Copper, having nearly double the initial force in fine wires, arrives at its maximum at 4 mm.; but brass creeps slowly up, passing copper at 5 mm., arriving at its maximum at 6 mm., and finally, in the large section 10 mm., it has more force than copper, their positions being completely reversed.

I have been unable to obtain wires of different diameters of other metals; but zinc rods of 10 mm. gave a still higher rate than brass, whilst in small diameters its force was less. For non-magnetic metals it is probable that the greater the specific resistance of the metal the greater will be the diameter of the wire before the fall commences.

Carbon is remarkably free from self-induction, and although there is a rise of force in rods of of 3 mm. to 10 mm., it is so small as to be hardly measurable. German silver rises with comparative rapidity, indicating that with wires of 20 mm. its force would equal that of copper. Carbon therefore seems peculiarly adapted as a resistance when used in the variable period of electric currents.

Influence of Parallel Currents.

The instrument being well adapted for showing the slightest change in the self-induction by the reaction of one portion of the current upon the other when in the same direction, as in a coil, or in the opposite direction, as in a parallel return wire, I made a series of experiments in order to observe the influence of different metallic conductors in this respect.

Two silk-covered iron and copper wires of similar diameter and length (1 mm. diam., 2 metres in length) were each formed in a single loop of 66 cm. diameter. The extra currents from iron were, as usual, six times stronger than those from a similar loop of copper. On closing the loop by bringing the opposite sides in close proximity and thus making a parallel return wire (the current ascending on one side and descending the other), I found that the reaction of currents in opposite direction was very different with different metals, the results depending more upon the nature of the metal than upon the proximity of the wires.

There was a reduction of the previous force of the extra currents in iron, when forming a parallel return wire, of 15 per cent., whilst the reduction in copper was 80 per cent. Thus the

* "Electricity and Magnetism," vol. ii., p. 291.

currents in copper are far more influenced by an external wire than those in iron; consequently a telephone line having its return wire in close proximity should invariably be of copper, as not only is its specific inductive capacity less, but this is again reduced by the return wire, so that its self-induction is far below that of iron.

In order to observe the influence of currents in the same direction, the same wires were formed into a close coil of twelve turns of 2 cm. diameter; and from the known effects of parallel currents in the same direction we should expect a greatly increased effect. It was so in the case of copper, but iron was far less under the influence of an external parallel current; the strength of current in iron when formed into a coil being 57 per cent. greater than that of a single wide loop, whilst in copper the increase was 404 per cent., or seven times the increase of iron; and although iron when in a single wide loop had six times the force of copper, the comparative strength was reversed when the wires were wound as a coil, the extra currents from the copper coil then having 14 per cent. greater strength than that from iron, and this difference could be rendered more evident by employing longer wires.

Thus copper, as regards extra currents, is far more sensitive to the influence of external currents than iron, and the true self-induction from its own current can only be obtained by a straight wire, where the return wire is at such a distance that its influence is not appreciable.

Reaction of Contiguous Portions of the same Current.

It is well known that currents in separate portions of the same wire (as in a coil) react upon each other, and I felt convinced from the preceding experiment that self-induction is entirely due to similar electro-magnetic reactions between contiguous portions of the current in its own wire. Let us assume that an electric current consists of a bundle or an almost infinite number of parallel currents, the limit being a single line of consecutive molecules; then each line of current should by its electro-magnetic action react on each of the others similarly to wires conveying separate portions of the current, and the self-induction should be at its maximum when the lines are in the closest possible proximity, as in a conductor of circular section, and far less when separated, as in one of ribbon form, where the outlying portions are separated by a comparatively great distance: there would still remain, in the latter case, the reactions from the near portions on each other, and these should again be reduced by cutting the ribbon into a number of thin narrow strips separated, except at their junction, to a sufficient distance to prevent any marked reaction.

My experiments prove that this assumption is an experimental fact; for we can reduce the self-induction of a current upon itself to a mere fraction of its previous force by simply separating as indicated the contiguous portions of a current from each other, the results proving that a comparatively small separation, such as is obtained by employing ribbon conductors in place of a wire of the same weight, reduces the self-induction 80 per cent. in iron and 35 per cent. in copper; and if we still divide the current by cutting the ribbon into several, say 16, strips (separating the strips at least 1 cm. from each other), then the combined but separated strips show a still greater reduction, being 94 per cent. in iron and 75 per cent. in copper.

The following table shows the comparative reduction of self-induction by employing ribbons and parallel separated wires:—

Table II.

Flat Strips compared with Round Wire 30 cm. in length.	Copper.	Iron.	Parallel Wires 30 cm. in length.	Copper.	Iron.
Wire 1 mm. diameter ..	20	100	Wire 1 mm. diameter..	20	100
Strips.			Single Wire.		
0·25 mm. thick, 2 mm. wide ...	15	35	0·25 mm. diameter	16	48
Same, 5 mm. wide	13	20	Two similar wires	12	30
„ 10 „ „	11	15	Four „ „	9	18
„ 20 „ „	10	14	Eight „ „	8	10
„ 40 „ „	9	13	Sixteen „ „	7	6
Same, strip rolled up in the form of wire	17	15	Same, 16 wires bound close together ...	18	12

The resistance of a conductor, or even the nature of its metal, has less influence on its self induction than the form given to that conductor, the 1 mm. wire in the above table having a less resistance than the strip of 2 mm. wide, and a greater than any of the wider strips; but through all these variations we notice a gradual fall from the wire to the widest strip or ribbon, with a marked return to its previous force when the ribbon is rolled up in the form of a wire.

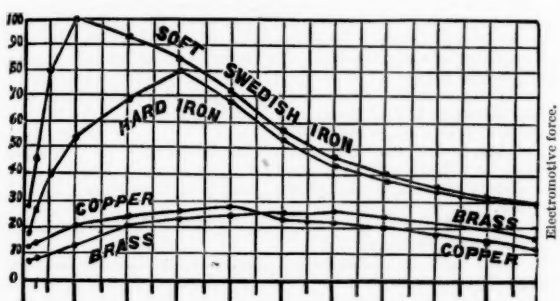
The reduction is greater in iron than copper, but its increase when rolled up is less than copper, thus agreeing with the previous observations on the difference of iron and copper to external reactions.

A still greater reduction takes place when we separate a current by using parallel wires separated 2 cm. from each other, as shown in the table. We then have a similar reduction to that produced by cutting the strips into several separate conductors; and we again remark that when the wires are brought close together (forming a stranded wire) copper rises in a far greater proportion than iron, the 16 fine iron wires twisted together as a stranded wire having 88 per cent. less induction than a solid wire of similar weight; a remarkable fact being that whilst a solid iron wire has an inductive capacity 80 per cent. greater than a solid copper wire, this is completely reversed when each metal forms a stranded wire of the same weight as the solid, for iron then has 33 per cent. less self-induction than copper.

It is not necessary to use extremely fine wires when we desire to reduce the inductive capacity of iron to that of copper, for I have formed stranded wire rope of 16 strands of wire where each wire was 1 mm. in diameter, giving 75 per cent. less induction than a solid wire of the same resistance. I purchased an ordinary wire rope of 6 mm. diameter, having 6 strands of 6 wires, each 0·5 mm. diameter; this gave the best result yet obtained, for, on comparing 3 mètres of it with a similar length of solid iron wire of the same resistance, the 36-stranded wire had only 5 per cent. of the amount of induction shown by the solid wire.

Steel, in the form of ribbon or stranded wires, shows a similar effect to that of iron; and it is a remarkable fact that, whilst the extra currents from a steel or iron wire 4 mm. in diameter are extremely slow, and impossible to balance without reducing the time of the sonometer current (by the introduction of an iron core), the ribbon or stranded wire requires no such compensation, for its feeble extra current is exceedingly sharp, and can be balanced to a perfect zero, being actually quicker than that of a solid wire of copper of the same resistance. This fact I regard as one of great importance for telegraph lines and lightning conductors.

A curious effect takes place if we employ mixed conductors, such as a compound wire of copper and iron. A fine coating of copper reduces the induction in a solid iron wire in a marked degree. This I found to be due to the difference of electromotive force of the extra currents in the two metals, for, by employing a fine copper wire parallel with an iron wire, and in contact at the ends, the extra current was reduced 60 per cent. The copper wire, having a lower electromotive force, probably acts as a shunt; but if the capacity of the iron has already been reduced, as in a sheet or stranded wires, then the addition of a single copper strand increases the force, as the electromotive force of the extra currents of copper is above that of stranded iron.



There has been for many years a discussion as to the merits of the round form as compared with the tape or ribbon form for lightning conductors. Those in favour of the former based their conclusions on experiments which gave a negative or no apparent difference between the two forms of conductors. Those in favour of ribbon conductors, as Sir W. Snow Harris, Professor Guillemin, and many others, based their opinion upon marked differences found when using high charges of static electricity. The latter supposed that there was a difference between discharges of static electricity and voltaic currents of low tension, and that the advantage recognised by almost conclusive experiments was due in a great measure to conduction by surface.

In the year 1864, Professor Guillemin and myself, as members of the Commission de Perfectionment of the French Telegraph Administration, were charged with the mission of testing the comparative merits of the lightning protectors then used upon their lines.

Our method of experimenting consisted in joining an insulated conductor to a short fine iron wire connected directly with the earth return wire. A Leyden jar battery charged by a Ruhmkorff coil was discharged through this conductor, burning or deflagrating the fine iron wire. This wire represented the telegraph instrument requiring protection, and by placing the lightning protector connected with the earth in advance of the fine iron wire we could observe the amount of protection afforded. This answered extremely well for feeble discharges, but with the full power of our battery the fine iron wire was invariably destroyed, even with the best lightning protectors which are universally used to this day. Noticing that we could not give absolute protection to the fine wire by lightning protectors, we tried the effect of joining the conductor direct to a separate earth wire in advance of the fine wire, and with powerful discharges the wire beyond the protection was invariably burnt, notwithstanding that we

connected the conductor direct to earth by a copper stranded wire of 1 cm. diameter.

Professor Guillemin continued these experiments after my departure for Russia, and he found, by employing a thin sheet of copper as a conductor to earth in place of the copper stranded wire placed in advance of the fine iron wire, that the wire could be perfectly protected. The theory of this action was not understood at the time, and the experiment has not received the attention it deserved; but the mutual reactions of contiguous currents shown in this paper explain the phenomenon in the fullest degree, for we see that a sheet or ribbon conductor has far less self-induction than a wire or rod of the same material.

I am fully convinced from the results of my experiments that an enormous retardation or resistance is evident in all conductors at the first portion of the variable period, and that this is due to self-induction, the current thus arousing an antagonist in its own path sufficiently powerful, when the primary current has a high electromotive force, to deflagrate or separate the wire into its constituent separate molecules, as shown by Dr. Warren de la Rue.

It is also evident from my experiments—which are easily repeated, with invariable results—that a flat conductor has far less self-induction than a solid or circular section during the variable period; and even with a constant current, as in the stable period, this form of conductor, as first shown by Professor George Forbes, would, from its greater radiation, convey more current with less heating than a wire or rod of the same resistance.

Lightning conductors are intended to convey a current of high intensity during an exceedingly short time, and should therefore be designed so as to convey this current with as little opposition from self-induction as possible; consequently I regard a solid rod of iron as the worst possible form for a lightning conductor. The conductor, if of copper, should be of ribbon form, say 1 mm. by 10 cm. wide, or if of iron, of numerous stranded wires or a wide ribbon of similar conductivity to that of the copper.

Self-Induction of a Telegraph Line.

A telegraph line may be considered as a single loop: the earth taking the place of a return wire can only affect the self-induction by a diminution of its effects, as in the case of a parallel return wire.

Mr. W. H. Preece has lately read a most valuable paper on "The Relative Merits of Iron and Copper wire for Telegraph Lines,"* in which he shows, by comparative rates of speed with the same instrument, that on a copper and an iron line of 278 miles in length (between London and Newcastle), whose resistance and static capacity were rendered equal, there was an increase of speed in the copper line of 12·9 per cent. as compared with an iron wire.

I have not been able to test the relative speeds obtainable by telegraph instruments on wires of different material. The results in every case would depend very much on the apparatus employed, but I have considered the question from a point of view independent of the instruments.

There is a remarkable difference in the resistance of a wire during the stable and the variable period, the measurements taken in the stable period giving no real or approximate idea of what its resistance really is during the rise of the current in the wire.

A curious fact in relation to telegraphy is that all measurements are made during the period of a constant flow of current, whilst all instruments—particularly those requiring rapid changes in the current—work only during the rise and fall of the current, as in the variable period. Telegraph engineers, however, have not made the mistake of assuming that there is no difference in the resistance of a wire in these two periods, as it is well known that electro-magnets and coils have a far higher resistance during the rise and fall of a current, and coils simply augment the effect of a straight wire of a given length.

The present method of testing by Wheatstone bridge has been adopted because we had no practical means of measuring the resistance in the variable period; and I do not believe that this can be accomplished except by a similar method to that which I have used, in which the resistance and self-induction are separately measured and balanced, and by the use of an exceedingly rapid and sensitive instrument of observation, as the telephone, in place of the sluggish galvanometers, no matter of what construction.

The speed of telegraph instruments is greatly influenced by the resistance of the wire. I said in 1883§ that a great difference would be found in the resistance of an electrical conductor if measured during the variable instead of the stable period, and I have made numerous experiments with a view of ascertaining to what extent this difference would probably be felt on telegraph lines.

I have already mentioned that the time or the duration of the extra currents increases rapidly with the section of the conductor; consequently comparisons can only be made between wires of similar section for speed, or wires of similar resistance for differences in their variable period.

In measuring the resistance of a wire during the two periods, I have found it best to avoid the use of resistance coils, the simplest method being to measure or balance a given length of wire in one period, and then observing how much lengthening or shortening of the wire would produce a similar zero in the second period. Suppose that we commence by balancing the resistance during the variable period, and fix the sliding communications at the point at which we have obtained a perfect zero; we can now change to the stable period by means of the commutator; and as we no longer find a zero, but extremely loud sounds, we gradually lengthen the wire under observation until we have again a perfect zero. The amount of wire added to its previous length shows the difference in resistance between a conductor in which there are rapid electrical changes and that wherein the flow of current is constant.

Amongst numerous experiments I will cite a single example. I measured or balanced the resistance of of an ordinary soft iron wire, 1 metre in length and 4 mm. diameter, during the variable period, and found that it required in the stable period exactly 2 metres 58 cm. to balance the previous resistance. Similar tests on a sample of best charcoal iron wire, as used on our telegraph lines, gave still more remarkable results, showing 225 per cent. difference between the two periods; for 1 metre of this wire had, during the rise and fall of the current, precisely the same resistance as 3 metres 25 cm. in the stable period. This shows that an iron telegraph wire has with rapid currents *more than three times* the resistance during its actual work than that supposed to be its true resistance.

It was difficult on short lengths to find any change whatever in the resistance of copper or stranded iron wires in the two periods; the time of discharge being excessively rapid, I could only estimate the resistance by the electromotive force of the extra currents, or by forming the wires into coils (when a remarkably great difference is shown), and then estimating the proportional amount due to its own reaction; by this method I was enabled to detect 10 per cent. difference for a solid copper wire, and but 8 per cent. for the stranded rope of 36 iron wires. The difference in time of the duration of the extra currents between solid iron and copper and between solid iron and stranded iron is so great that we may consider a solid iron wire to belong, comparatively speaking, to the class of slow conductors, whilst copper and stranded iron would belong to the rapid.

I have shown a difference of resistance in the variable period between copper and iron of at least 200 per cent.—a difference which will be felt on instruments depending upon rapid changes, such as the telephone; and it is evident that the more rapid the contacts of a telegraph instrument the greater will be the difference between copper and iron. There is consequently a great electrical advantage in those instruments which require only a single current for each letter, as the economy of electrical impulses allows them to work at a comparatively high speed; the duration of the extra currents would be shorter than the length of their contacts, and consequently they would perceive very little, if any, difference between the two periods, or between iron and copper. If we use three or five currents for each letter, we must necessarily send them faster or closer together; and the difficulty increases in a rapid ratio with the speed of intermittent or reversed currents, until a point is reached (as I have shown in the case of best charcoal iron) where, whilst nominally working through 500 miles, we are practically working through an equivalent resistance of at least 1,500 miles, and this without taking into account the static charge, which would, in addition, from its comparatively extreme slowness of charge and discharge, cause the apparent resistance of the wire in the variable period to be much greater than I have mentioned.

In Mr. Preece's experiments he finds a difference of speed of 12·9 per cent. between iron and copper, which is far less than the difference of resistance during the variable period which I have obtained; and this may be explained by assuming that the speed of the reversed currents which he employed was only near the border land of extra currents. I am convinced that if Mr. Preece could have increased the speed of the instruments he would have found a far greater difference between iron and copper; and if I regard the results of a solid iron wire alone, I should consider iron as unsuitable for telegraph instruments requiring extremely rapid currents. Copper would reign supreme if it were not for the fact, which I have discovered, that stranded iron wires have even a greater rapidity of action than copper.

Physical Changes in the Conductor.

Self-induction not only depends on the nature and form of its conductor, but also on the physical state of the metal, as already shown in the case of soft and hard iron. I felt convinced that the higher force in iron was due to its magnetic capacity, and to prove this I tried the effect of heating the wire to a bright red heat, or 1,000° Cent. It is well known that iron loses its magnetic properties at bright red heat, and I found that its self-induction then fell to less than that of copper. This would have been conclusive had it not been for the fact that a different result takes place when the capacity of the iron for self-induction has already been reduced, as in the case of thin flat sheets of iron: in this case there is no disappearance or further decrease of induction except that due to the extra resistance caused by the increased temperature of the strip. Now, as the strip was highly magnetic when cold, and lost this property at red heat, there should have been some change in its self-induction if this were due to the magnetic nature of the iron alone. This requires further researches before a probable explanation can be given.

Iron is peculiarly sensitive to all physical changes. Mechanical strain of all kinds hardens the wire, and its influence on its

* British Association, Aberdeen, September, 1885.

† Discussion on the paper of W. H. Preece on Electrical Conductors, *Proc. Inst. Civil Engineers*, vol. lxxv., 1883.

self-induction can at once be detected. An iron wire under a moderate longitudinal strain loses 40 per cent., and its capacity is then less than unstrained cast steel.

Iron well annealed has much less resistance than the same iron when hard drawn, and soft iron is generally employed for telegraph lines; but during the variable period a curious reversal takes place, as then soft iron has a higher resistance than hard iron. This apparent anomaly is easily explained if we compare the far higher self-induction of soft iron. Work is done at the expense of electrical energy, and the apparent higher resistance is due to the greater electro-magnetic action in soft iron.

An iron wire shows traces of remaining circular magnetism after the passage of a continuous current, reducing the following extra currents 10 per cent.

Magnetising the wire, or subjecting it to mechanical vibrations, when used separately, produce no apparent change in its inductive capacity, but a remarkable change takes place if either of these is used in conjunction with a constant current. Let us pass a constant current and heat the wire to red heat, allowing it to cool with the current on; or, in place of heat, magnetise the wire; or, in place of magnetism, give the wire mechanical vibrations: the result of either of these being a strong internal circular magnetism, due, I believe, to the loosening of the magnetic molecules, allowing them to rotate with greater freedom under the influence of heat, mechanical vibrations, or magnetism. A wire thus treated has no longer its previous self-induction, which has fallen 60 per cent.; and as the circular magnetism becomes fixed when the vibrations cease, this molecular structure remains a constant as long as we employ intermittent currents in the same direction, but the structure disappears the instant a reverse current is sent; and this explains why we have more than double the amount of self-induction from reverse currents, as each reversal destroys any remaining magnetism due to the previous passage of the current.

If we compare the electromotive force of self-induction on a given length of wire with the secondary currents generated in a second but independent circuit, we find that the self-induction is the most powerful, the secondary currents generated in a close independent copper wire being 20 per cent. less than its own wire. There is no difference between the self-induction of a current and the secondary currents; they are, in fact, as proved by Faraday, part of the same phenomenon. The self-induction is evidently due to the electro-magnetic reactions of the primary current, and as magnetism permeates space, the separation of the wires only serves to insulate the primary, but does not affect its magnetic, influence; and, as I have shown in the reactions of contiguous portions of the same current, so the magnetic reactions perpendicular to the axis of the current continue through the wire to all surrounding wires; and if we call the currents in the independent wire secondary, they are still secondary whilst enclosed in the wire of the primary; and as the reaction will ever be the strongest in the axis of the current, so will these currents be necessarily stronger than those induced in independent wires. For this reason we should be able to obtain extra-currents of far higher electromotive force than would be possible from a secondary wire of the same length.

It was my intention, on the reading of this paper, to demonstrate by practical experiments some remarkable properties of extra currents of high electromotive force; but I find that the subject and apparatus employed require a longer description than the limits of this paper allow. I must also leave aside for the present my experiments upon coils of different forms with cores of different metals. These, as well as other results obtained, indicate that there is a large field of useful research in many directions, each, however, requiring special studies according to the object we may have in view.

The record of numerous experiments, of which this paper is only an abstract, shows that the nature of the metal as well as its physical condition has an important influence upon the self-induction of an electric current, and by a study of the reactions produced by the contiguous portions of a current, and by application of the results, we may, as in the case of iron, transform an extremely slow conductor into one of the greatest rapidity; I therefore hope not only that these researches may be of interest from a scientific point of view, but that the results obtained may be of practical utility in some of the numerous applications of electricity.

The meeting then adjourned.

Physical Society, January 23rd.

Prof. GUTHRIE, President, in the Chair.

THE following communications were read:—"A note on the paper by Prof. W. Ramsay and Dr. S. Young, on some Thermodynamical Relations," by Prof. W. E. AYRTON and Prof. JOHN PERRY. The authors, after referring in the highest terms to the careful experimental work of Messrs. Ramsay and Young in their investigation upon "Some Thermodynamical Relations," the results of which were communicated to the Society at the last meeting, show that the four laws stated in their paper are in reality only one, since if any one of them is assumed the remaining three may be deduced from it. Hence it is sufficient to examine only one, and of the four the third is in the form that can be most readily tested. This law, the statement of which is, that for all substances at any given pressure the product $t \frac{d p}{d t}$ is constant, p being the pressure and t the absolute temperature of saturated vapour at that pressure, is represented mathematically thus—

$$t \frac{d p}{d t} = \phi (p) \qquad (1)$$

$\phi (p)$ being a function of the pressure, independent of the substance. Writing this equation

$$\frac{d p}{\phi (p)} = \frac{d t}{t}$$

and integrating, we get

$$t = a \psi (p) \qquad (2)$$

$\psi (p)$ being also a function of the pressure only, and a a constant depending only upon the substance employed. It is in this form that the authors have examined the third law; if true, it follows at once from (2) that the ratio of the temperatures of two saturated vapours to one another at any pressure is the same as the ratio at any other pressure. It is seen, however, either by reference to Regnault's numbers, or Rankine's formula

$$\log. p = d - \frac{\beta}{t} - \frac{\gamma}{t^2}$$

an expression based upon his molecular theory, and which, as remarked by one of the authors at the last meeting, agrees with Regnault's results with remarkable closeness, that this ratio is far from constant. The authors are therefore compelled to conclude that the expressions given by Prof. Ramsay and Dr. Young must not be regarded as absolute laws.

"A note on the paper by Prof. J. W. Clarke, On the Determination of the Heat-capacity of a Thermometer," by Mr. A. W. CLAYDEN. The author has applied a correction to an expression given by the late Prof. J. W. Clarke for measuring the heat-capacity of a thermometer, in a paper communicated to the Society at a previous meeting (April 25th, 1885). Prof. Clarke's expression was affected by the mercury not entirely filling the bulb and stem of the thermometer. The corrected expression obtained by the author is

$$v_1 = \frac{v (s - s_2)}{s_1 - \frac{s_2 (1 + \beta t)}{1 + a t}}$$

s, s_1, and s_2 being the mean densities of the instrument, mercury and glass respectively; β and a the co-efficients of voluminal expansion of mercury and glass; v and v_1 the volumes of the instrument and of the mercury.

"Note on Some Organic Substances of High Refractive Power," by Mr. H. G. MADAN. In the course of some correspondence respecting M. Bertrand's polarising prisms, the author was informed that the cement used was napthyl-phenyl-ketone dibromide. He has consequently prepared specimens of the ketone and subjected them to optical examination. The ketone is a thick yellow oil, boiling at a temperature near the boiling point of mercury; it appears to be a very stable, neutral, and harmless substance like Canada balsam, but, unfortunately, it does not appear to be capable of hardening, and hence it is not by itself adapted for a cement. Its refractive index for the D line is 1·666, higher than that of carbonic sulphide, while its dispersive power is approximately the same as that of that substance. The author has made the bromide of the ketone referred to above, but it seems liable to decompose, with formation of hydro-bromic acid, which acts upon the spar. Mr. Madan also exhibited a specimen of metacinnamene, a highly refracting glass-like solid obtained by the action of light or heat upon cinnamene. This substance possesses a refractive index of 1·593 for the D line and would make a valuable cement if it showed a firm adhesiveness for glass.

The PRESIDENT exhibited and described an instrument he had made in the course of an acoustical investigation upon which he had been engaged. It is a musical instrument similar in principle to the harmonicon. In the case of the harmonicon the rectangular plate is usually supported by strings passing through the nodes, but the author wished to make an instrument that could be "bowed." The "nodes" are not absolute positions of rest, the particles at them describing curves having cusps pointing outwards. The plan adopted was to solder two springs to the plate, which was of brass, the points of attachment being slightly outside the nodes, and the springs being such as to give the same fundamental note as the plate. The other ends of the springs were attached to the mouth of a resonator whose fundamental note was also that of the plate. The plate when struck or bowed gave a tone very like that of a tuning fork; and in a discussion that followed,

Prof. S. P. THOMPSON suggested the possible use of these instruments as a substitute for a series of forks, the cost of a complete set of which often places them beyond the reach of the student.

Prof. MCLEOD suggested that the springs should be tuned to the octave of the plate instead of to its fundamental, and that they should have a slightly different form.

NEW PATENTS—1886.

893. "Supports or holders for incandescent electric lamps." A. SWAN. Dated January 20.

932. "Dynamo-electric machines." A. LE N. FOSTER, F. V. ANDERSEN. Dated January 21. (*Complete.*)

955. "Electric plug switches." C. HALL, H. C. HAROLD. Dated January 21.

956. "Lanterns for directing the light of ordinary electric arc lamps horizontally." C. HALL, H. C. HAROLD. Dated January 21.

958. "Means for preventing the falling of broken telephone, telegraph or like overhead wires." F. C. FREEMAN. Dated January 21.

973. "Switch to control one incandescent electric light." T. and H. BAYLEY. Dated January 22.

974. "Economic bell battery." A. ALLMARK. Dated January 22.

993. "Combination of an electric alarm bell attachment to a hook or peg or hooks or pegs used for hanging or suspending goods, &c." S. P. WESTON. Dated January 22.

997. "Acoustic or mechanical telephones." CORDNER, ALLEN AND CO., T. M. COLLET, H. COLLET, G. L. ANDERS. Dated January 22. (*Complete.*)

1011. "Construction or arrangement of dry electric battery with regenerative and self-sustaining power." A. RETTICH. Dated January 22.

1028. "Telephone receiver with movable armatures." E. H. ANDREOLI. (Communicated by J. Boisselot.) Dated January 23.

1034. "Electrical conductors." G. SUTTON, HENLEY'S TELEGRAPH WORKS COMPANY. Dated January 23.

1044. "Constructing and fitting electrical insulators." J. E. GRIFFITH. Dated January 23.

1054. "Construction or formation of plates with composition for electric batteries." J. H. NOAD, R. MATTHEWS. Dated January 23.

1067. "Galvanic batteries." T. CAINE. Dated January 25.

1096. "Incandescing electric lamps, and systems of electric lighting." B. J. B. MILLS. (Communicated by L. Stieringer.) Dated January 25.

1099. "Mechanical telephones." O. SHINNER. Dated January 25.

1125. "Distributing electricity by means of secondary generators or transformers." W. H. SNELL. Dated January 26.

1150. "Electro-dynamic motors." T. J. HANDFORD. (Communicated by F. J. Sprague.) Dated January 26.

1151. "Galvanic batteries." W. W. POPPLEWELL. (Communicated by F. La O. Lathrop, J. W. Carter and C. Faber.) Dated January 26. (*Complete.*)

1160. "Smelting ores by electricity." W. P. THOMPSON. (Communicated by A. H. Cowles.) Dated January 26. (*Complete.*)

1192. "Insulating stands." O. E. WOODHOUSE, F. L. RAWSON. Dated January 26.

1193. "Incandescent electric lamps." O. E. WOODHOUSE, F. L. RAWSON. Dated January 26.

1196. "Actuating mechanism for electro-static generators and applications thereof." J. G. LORRAIN. Dated January 26.

1197. "Electric street fire-alarm." F. E. STUART. Dated January 27.

1220. "Electric clocks." J. CASSEY, J. F. DIXON. Dated January 27.

1246. "Thermo electric piles." R. F. VENNER. Dated January 27.

1250. "Electrical contact apparatus." C. O. VARLEY. Dated January 27.

1277. "Utilising and applying clockwork as a motive power for machines for generating electricity." G. SAUZE. Dated January 28.

1284. "Regulation and control of the electrical currents from secondary generators." J. A. KINGDON. Dated January 28.

1292. "Telephones." H. EDMUNDS. (Partly communicated by S. Thornberry.) Dated January 28. (*Complete.*)

1309. "Resistance boxes and like apparatus for use in electrical circuits of any kind." G. A. NUSSBAUM. Dated January 29.

1310. "Telephone transmitters." W. P. THOMPSON. (Communicated by E. J. Gilliland.) Dated January 29. (*Complete.*)

1313. "Incandescent lamp holders." W. A. S. BENSON. Dated January 29.

1320. "Secondary batteries." A. RECKENZAUN. Dated January 29.

1322. "Portable electric burglar alarms." L. C. DETTMER. Dated January 29.

1337. "Electrical switches." F. L. RAWSON, J. H. DAVIES. Dated January 29.

1340. "Dynamo-electric machines." G. C. FRICKER. Dated January 29.

1354. "Electrode for secondary batteries." H. J. ALLISON. (Communicated by E. M. Gardner.) Dated January 30. (*Complete.*)

1375. "Galvanic batteries." R. M. BAILY, A. GRUNDY. Dated January 30.

1382. "Clearing ships' telegraph cables." H. J. ECK, E. A. WOOD. Dated January 30.

1410. "Incandescent electric lamps." C. BAKE. Dated January 30.

1415. "Primary and secondary electric batteries." N. J. CONTARINI, T. WRIGLEY. Dated February 1.

ABSTRACTS OF PUBLISHED SPECIFICATIONS, 1885.

562. "Improvements in connection with telegraph, signal, and like poles or standards, for steadying and retaining them in position." W. B. INCLEDON. Dated January 15. 8d. Consists in combining with that portion of the pole, or its equivalent beneath the earth, a steadying plate formed and attached in novel manner. The said plate has two parallel surfaces in different planes, connected by a curved or bent portion, through which, and the post or its equivalent, bolts are passed at right or other angles to each other, so as to firmly secure the plate and pole together, in whatever direction strains may be caused to act on them.

1701. "Improvements in dynamo-electric machines." M. H. SMITH. Dated February 7. 11d. Comprises two "horse shoe" or bridge shaped electro-magnets, so placed and wound that the south pole of one magnet is opposite the north pole of the other, making two separate magnetic fields, in which two separate armatures revolve attached to a spindle, passed through them, having the commutators in the middle or between the armatures, the bearings or journals of the spindle being at the outside.

1785. "Improvements in apparatus for lighting railway carriages by electricity." A. M. CLARK. (Communicated from abroad by the Maschinenfabrik Esslingen and the Electrotechnische Fabrik Cannstatt, of Germany.) Dated February 9. 1s. 3d. Has for its object the lighting of railway trains or single carriages, whether travelling or stationary, by the incandescent electric light, one or more dynamo-electric machines and one or more accumulators being employed.

CORRESPONDENCE.

The Dynamo as a Generator and as a Motor.

Kindly allow me space for a few lines rendered necessary by the references in your issue of January 22nd to my paper on the above subject.

I am glad to see from Mr. Brain's interesting letter that his experience accords so completely with the principles and view indicated in the paper. With regard to the question of the efficiency of electric motors, I wish to point out that the tabulated figures given in my paper are not to be taken as indicating a low efficiency. An unascertained loss in transmission was *not included* in the horse-power readings, and should, therefore, be added to them. By a clerical error this unascertained loss is stated to be *included* in the horse-power column. As a matter of fact, other experiments show that the commercial efficiency of the "Victoria" motors (or the ratio of the power delivered in a useful form at the pulley, to that absorbed at the terminals) is over 80 per cent. with full load.

In the remarks which you quote from M. Hospitalier's article, a reference is made to the use of motors without iron in the armatures. Of course I am aware—and sufficiently indicated in the paper—that iron is no more a necessity in the armature of a motor than in that of a generator. The almost universal practice, however, shows that its use is attended with great practical advantage from a structural point of view.

I am glad to say that since writing the paper I have seen reason to considerably modify the view therein expressed as to the amount of the effect produced by the difference of the character of the induction of eddy currents in generators and motors. The difference will probably not be found of such importance as to furnish a very strong argument against the use of iron in the armatures of the latter.

W. M. Mordey.

Blue Photos from Tracings.

Some three months ago Mr. Hett asked in your columns whether it is practicable to print blue photos with a single glow lamp.

We make constant use of this process, and find that in such weather as this, when it takes all day to produce even a faint impression, we can get a capital print in ten minutes at 10 inches from a 25 ampère arc.

The actual candle-power is probably about 1,600 C.P., as the carbons were not set for a condensed beam (nominal 6,000 ?). A 20-candle glow lamp would require 12 to 14 hours to do the same even if it were of the same actinic power. But it is not, and it would probably take 60 to 80 hours.

Alex. P. Trotter.

Dynamos.

I feel it necessary to say a few words in reply to the remarks of Mr. Crompton and Mr. S. Walker. It is in no way my desire to make an attack on dynamo makers. My wish is to point out that competition carried too far is to the disadvantage of the purchaser who, in most cases, has but little knowledge of electricity.

What Mr. Crompton says of the first machine supplied to me is true, but it was sent knowing what it had to do, and for this reason the exchange was made, having failed. In speaking of running cool, I refer to the shunt. The two Crompton and two Siemens machines all get very warm, but not dangerously hot; still this should not be so, it is so much loss of power, and it cannot be an advantage apart from this. The cost of the large Elwell-Parker machine, I believe, to the public is less than the dynamo supplied to me by Messrs. Crompton, so clearly on this head there is an advantage.

It is right to state what the total requirements here are :—For house, stable and engine house, 100 ampères at 110 volts : for workshop the same. Hence 200 ampères are required at the maximum and the Crompton machine was set up to do half the work, and the large Siemens to do the other half. The Elwell-Parker dynamo, I believe, will do the two put together and forms a reserve. The reason for ordering all dynamos to give 130 volts is, that I require this E.M.F. for charging the cells when giving 35 to 40 ampères, and in consequence of the falling curve of simple shunt machines; the advantage I gain is that the dynamo may run far slower than intended by the manufacturer. The plan is a good one, for I have rarely found a maker keep within the speed specified. Here is a case. The new Crompton dynamo is now in its place and has been running a few days. The specified speed was under 600 revs. per minute for 130 volts. By test 630 were required. Ampères maximum 125. For 40 ampères I find the E.M.F. about 140 to 145 volts, so I have lowered the speed to 580. Then, again, if cells are ever made which may be charged more rapidly, the speed can always be raised, which would not hold good if used at the maximum speed in the first instance. Judging by the size of the wire on the Crompton dynamo as compared with the Elwell-Parker, I should not be afraid of taking 250 ampères from the latter for many hours together.

Mr. Walker asks what is the commercial efficiency of the Elwell-Parker machine ? It can be answered thus. The loss in the armature is very small indeed, and the shunt current, during tests made, was 3·5 ampères. After taking the first 40 ampères from this machine, I found for all increase of current in the *outer circuit*, 1·1 I.H.P. gave 1 E.H.P. as nearly as possible, so that 90 per cent. approximate is the reply. I am making a number of tests with this machine and the Crompton and will publish the results when completed, and give the methods employed to permit of criticism. Mr. Walker appears to enquire whether my saving of 14s. a week is supplemented by some other outlay. The answer is *no*. The idea of a standard testing laboratory is good, and I shall rest satisfied if my communication does no more than cause such a movement to be set on foot. Before concluding, I must thank both your correspondents for the friendly spirit which they have shown, and it is right to add that I have been able to place three of Mr. Crompton's machines in installations, in order to show your readers that I am no enemy of them, but I wish to see these machines perfected.

David Salomons.

Broomhill, Tunbridge Wells,
February 1st, 1886.

Without making any statements regarding the maximum capacity of the Elwell-Parker dynamo referred to by Mr. Crompton, which, coming from an interested individual, might not be considered of the highest value, I hasten to say, in reply to the good suggestion and substantial offer made by him, that Messrs. Elwell-Parker would hail with the greatest pleasure any public trials of dynamos, and would willingly contribute towards the expense of carrying them out in a thoroughly satisfactory manner.

My great regret is that such tests were not made two years ago, when some manufacturers were much farther behind than they now are.

P. Bedford Elwell.

8, Wilton Place, S.W.,
February 3rd, 1886.

Telephone Patents.

Allow me to point out that the quashing of the "Bell" patent in this country, should it occur, would have little or no effect on the present telephone monopoly, as it is the "Edison" and not the Bell patent that at present bars the way to telephonic extension.

While on this subject, I may mention that I observe from a contemporary that the United Telephone Company are about to proceed against a Liverpool gentleman for infringement on account of his having used the Silvanus Thompson instruments of the "New" Telephone Company.

It appears to me that it is rather a hole-and-corner proceeding to take action against a private individual instead of acting direct, and sueing the manufacturers themselves.

"Telephonist."

Efficiency per Pound of Copper.

Mr. Sidney F. Walker, in his interesting letter which appeared in your last issue, omitted, I think, one very important fact when writing on the above subject. If we wish to get such a thing as efficiency per pound of copper in our dynamos, we must use only the softest and purest quality of iron in the field-magnets and armature or, in other words, we must use iron of small coercive force. It appears to me, however, that this term efficiency per pound of copper, is not only uncalled for, but is quite misleading ; and I agree with what Mr. Walker says or aims at in his letter, viz., that a machine ought to be judged according to its commercial value.

When a man wants to buy a dynamo he asks, "How much does it cost ? What will it do ? How much power does it require to drive it ? What maintenance does it require ? How long will it last ? Is it thoroughly practicable and reliable ? Does it require much attention ?" and such like questions. Imagine a dynamo maker replying as follows :—

"In reply to your enquiries I beg to say that my machines may perhaps be a little more expensive than those of other makers, and may require a little more power to drive it, in order to work the requisite number of lamps. It may also require more attention than some other machines ; but all these slight defects are fully compensated for, as my machine has a *greater efficiency per pound of copper* than any other machine in the market."

Where do your readers think such a letter would go ? Why, in the waste-paper basket, of course.

Charles Lever.

Bowdon, Cheshire.